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RMA CONTAMINATION CLEANUP

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13. ABSTRACT (Maximum 200 words)

THE 1989 SURFACE WATER REPORT IS DIVIDED INTO SIX SECTIONS AND TWO APPENDICES. SECTION 1 PROVIDES A GENERAL HISTORICAL REVIEW OF THE DEVELOPMENT OF THE RMA. THE HISTORICAL ROLE OF SURFACE WATER FEATURES AT RMA, THE EFFECTS OF RMA INDUSTRIAL ACTIVITIES ON SURFACE SYSTEM MORPHOLOGY, AND THE MAJOR DRAINAGE BASINS THAT EXIST ON RMA ARE PRESENTED IN SECTION 2. SECTION 3 PROVIDE A DETAILED DISCUSSION OF THE PRESENT CMP PROGRAMS STRATEGIES AND METHODOLOGIES. SECTION 4 PRESENTS THE WATER QUALITY AND QUANTITY DATA COLLECTED DURING FISCAL YEAR 1989. SECTION 5 INTERPRETS THE COLLECTED SURFACE WATER DATA. SECTION 6 PROVIDES CONCLUSIONS AND A DETAILED SUMMARY OF FY89 RESULTS.
APPENDIX A INCLUDES INFORMATION RELATED TO SURFACE WATER QUANTITY AND APPENDIX B INCLUDES INFORMATION RELATED TO SURFACE WATER QUALITY.

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4.0 PROGRAM RESULTS

4.1 Surface-Water Quantity Results

This section presents hydrologic information that was obtained during Water Year 1989. Appendix A contains all detailed water quantity information compiled during Water Year 1989. This information comprises climatic, stream, lake and pond data, including results from each component of the surface-water monitoring network that was established under previous contracts and newly established during Water Year 1989. The components of the surface-water quantity program addressed in this section are gaging station data, lake and pond data, discharge to streams, lakes or channels that originate on RMA, and climatological data. The climatic data includes RMA temperature, precipitation and evaporation conditions. Volumes were calculated for lakes, streams and effluents (e.g., Sewage Treatment Plant), and are presented in this section. Hydrographic analyses are presented for surface-water trends and extremes for all stations during Water Year 1989. A historical review of the trends and extremes for the South Uvalda station are also presented in this section for Water Years 1986 and 1987.

4.1.1 1989 Climatological Conditions

Surface water at RMA is affected by the prevailing climatic conditions. The Water Year 1989 climatic conditions for RMA are based on weather information obtained from the CMP Air Element on RMA, the National Weather Service station located two miles south of RMA at Stapleton Airport and on evaporation information obtained from Cherry Creek Reservoir. It is assumed that there is minimal variation between Stapleton Airport and actual RMA weather conditions. A comparison of these data will be addressed in this report, but Stapleton data will be used for all analysis because the CMP Air element meteorological data was incomplete during Water Year 1989. Table 4.1-1 and Figure 4.1-1 summarize Water Year 1989 weather statistics, which include monthly temperature, precipitation and evaporation data. Appendix A-11 contains tables and figures that present complete average daily and monthly weather statistics.

Temperatures at RMA followed a normal trend of decreasing temperatures from September to January and increasing temperatures from January to August. The average annual temperature for Water Year 1989 was 50°F, with an average daily maximum of 86°F recorded on July 8, and an average daily minimum of -13°F recorded on February 4. The highest average monthly temperature was 76°F, which was recorded in July. The lowest average monthly temperature was 20°F, recorded in February.

Table 4.1-1 Monthly Averages of Temperature, Precipitation and Evaporation Data, Water Year 1989

DATE	CMP AIR ELEMENT* Average Temp (F)	CMP AIR ELEMENT* Total Precipitation (inches)	STAPLETON AIRPORT** Average Temp (F)	STAPLETON AIRPORT** Total Precipitation (inches)	CHERRY CREEK*** Total Evaporation (inches)
October 1988	52.77	1.32	54.19	0.06	4.80
November 1988	38.55	0.07	39.58	0.47	2.70
December 1988	29.10	0.13	31.35	1.04	0.90
January 1989	33.42	0.23	33.74	1.14	0.70
February 1989	17.74	0.13	20.23	0.66	0.90
March 1989	41.32	0.06	43.55	0.56	1.60
April 1989	47.94	0.04	49.58	1.00	3.20
May 1989	57.19	3.74	59.23	3.83	6.80
June 1989	60.97	1.58	63.55	2.04	6.94
July 1989	74.35	0.51	76.13	1.64	9.98
August 1989	69.42	0.69	71.90	1.28	7.64
September 1989	58.74	1.54	60.65	1.55	6.80
Monthly Averages	48.46	0.84	50.31	1.27	52.96
YEARLY TOTALS		10.04		15.27	

* CMP, Air Element Annual Report, 1989.
** NOAA Monthly Summaries, Stapleton Airport Weather Station.
*** Department of Defense, Corps of Engineers, Cherry Creek Reservoir.

Evaporation followed a normal decreasing trend from September to January and a typical increasing trend from January to August. Average monthly evaporation rates ranged from 0.70 in/mo in January to 9.98 in/mo in July, and averaged 4.41 in/mo and 0.15 in/day for the entire Water Year 1989. The total annual evaporation was 52.96 inches. All these values are based on data collected at Cherry Creek Reservoir. Lake evaporation, in this case, has been determined from a nomograph for Cherry Creek Reservoir. The nomograph determines evaporation by using mean daily temperature, solar radiation, mean daily dew point temperature and wind movement data.

The average annual water year precipitation for the Stapleton Airport area is 15.25 in, with a maximum of 23.3 in recorded in 1967 and a minimum of 7.51 in during 1954. Total precipitation for the Water Year 1989 was 15.27 inches. The highest monthly total was recorded in May, which was 3.83 in, and the lowest, 0.06 in, was recorded in October. A nine day period of rain was recorded during Water Year 1989 beginning on May 8 and ending on May 16. This rain event recorded 2.59 in of precipitation. Frequent summer thunderstorms can contribute significant amounts of precipitation on RMA. Some areas of RMA may receive measurable amounts of precipitation while other areas of RMA may receive none at all. The acquisition of a complete CMP Air Element Precipitation record will document this phenomena in the future. The total amount of precipitation recorded during the summer months from June to September was 6.51 inches. The highest monthly total was 2.04 in recorded in June, and the lowest amount was 1.28 in recorded in August. The highest summer storm event was recorded on July 29, which was 1.44 inches. Total monthly precipitation was lower than total evaporation in every month except December and January. Yearly precipitation was less than one-third that of yearly evaporation with evaporation exceeding precipitation by nearly 38 inches.

4.1.2 Stage-Discharge Relationships

Surface-water-discharge records (Appendix A-8) for the Water Year 1989 were produced for 11 continuous-recording surface-water gaging stations in the RMA drainage basins . The only drainage basins that require surface-water quantity monitoring at RMA are Irondale Gulch, First Creek and South Platte drainage basins. The other drainage basins (Sand Creek and Second Creek) do not display significant flows on RMA and gaging stations are not located in these drainages. The continuous water-discharge records were produced for each station by reducing both daily strip chart stage records and/or CR-10 data logger records to daily digitized stage records and by converting stage to discharge by a stage/discharge relationship established from each stations' rating curve.

The gaging stations included in the Irondale Gulch drainage basin are:

Havana Interceptor (SW11002)
Peoria Interceptor (SW11001)
Ladora Weir (SW02001)
South Uvalda (SW12005)
North Uvalda (SW01001)
Highline Lateral (SW12007)
South Plants Ditch (SW01003)

The gaging stations included in the First Creek drainage basin are;

South First Creek (SW08003)
North First Creek (SW24002)
First Creek Off-Post (SW37001)

The gaging station included in the South Platte drainage basin is;

Basin A (SW36001)

Water-discharge records for the winter months were not collected because freezing conditions inside the stilling well caused the float and pulley to dysfunction at each gaging station. The freezing problem should be alleviated in the future with the installation of the CR-10 data logger/bubbler system in April 1989. Missing records are shown as blanks on the water-discharge records (Appendix A-8). Generally records were missing during the freezing months of December through April. Estimated records for periods of incomplete or unrecoverable data are listed in the remarks section for each station on the water-discharge records (Appendix A-8) and are outlined in Section 4.1.2.1. Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards, where "excellent" means that about 95 percent of the reported daily mean discharges for a specified period are within ±5 percent of actual; "good" within ±10 percent; "fair" within ±15 percent; and "poor" means that about 95 percent of the reported daily mean discharges have less than "fair" accuracy (Rantz, 1982). The daily mean discharges reported for each station vary from good to poor.

4.1.2.1 Continuous Stage Data. One step in determining daily water-discharge records for the 11 monitoring stations was to convert daily strip-chart-stage records and CR-10 data logger records to daily digitized-stage records. The CR-10 data loggers are installed at South First Creek, North First Creek, South Uvalda and Havana Interceptor. The water discharge records at the stations with the CR-10 data loggers were developed primarily from the CR-10 data logger stage records. Surface-water continuous stage records for Water Year 1989 were produced and digitized for 11 stations. Continuous records were not produced for the winter months because of freezing conditions. This section details the conditions that may have affected each stations' stage record. The digitized stage records for the 11 stations are presented in Appendix A-7.

4.1.2.1.1 Havana Interceptor. - The continuous stage record for Water Year 1989 is considered to be good. No records were estimated for the station. The station operated a Stevens Type F recorder (analog) early in the water year and a Campbell Scientific CR-10 data logger (digital) later in the water year. The equipment was not operated simultaneously. Some irregularities and inaccuracies, which were primarily in the strip chart or Stevens record were caused by the following conditions:

- The stilling well was improperly located in the middle of the channel and was not hydraulically connected to the channel with intake pipes. The structure was removed in March 1989 and a CR-10 data logger and bubbler system was installed;

- Excessive amounts of sediment accumulated on the bottom of the channel and inside the stilling well, causing a problem during October and November while the Stevens Type F recorder was still operating;

- The float occasionally was stuck or hung-up on the corrugated metal stilling well pipe;

- A minimum stage of 0.12 ft was required to buoy up the float;

- Sage brush and trash occasionally accumulated on the upstream side of the stilling well and at the end of the channel, causing a backwater effect; and

- All of the above problems were not observed with the installation of the bubbler system.

4.1.2.1.2 Peoria Interceptor. - The continuous stage record for Water Year 1989 is considered to be good. No records were estimated for this station. Some irregularities and inaccuracies in the stage record were caused by the following conditions:

- The station displayed backwater conditions caused by high water levels at Havana Pond;

- The intake pipes leading to the stilling wells accumulated excess silt; and

- Trash and vegetative debris accumulated in the control section.

4.1.2.1.3 Ladora Weir. - The stage record for Water Year 1989 is considered to be good. Any irregularities or inaccuracies in the low-flow record were caused primarily by a leaking weir located at this station. High-flow records that predominate at this station are considered to be accurate.

The strip chart record was estimated for the following period due to recorder malfunctions:

- July 7, 1989 to July 20, 1989.

4.1.2.1.4 South Uvalda. - The continuous stage record for Water Year 1989 is considered to be good. In the first part of the water year the station operated only a Stevens Type F recorder. From mid-April through September the station operated both the Stevens Type F recorder (analog) and a Campbell Scientific CR-10 data logger (digital) simultaneously. The CR-10 stage record was used primarily from April to September. Some irregularities and inaccuracies in the strip chart record were caused by the following conditions:

- Excess debris, such as vegetation and trash, accumulated in the channel, in the control, and around the staff gage; and

- Intake pipes accumulated silt, causing a lag time between channel and strip chart response.

The strip chart records were estimated for the following periods due to recorder malfunctions and unrecoverable records:

- March 28, 29, 30, 1989; and

- April 3, 4, 9, 10, 11, 1989.

4.1.2.1.5 North Uvalda. - The continuous stage record for Water Year 1989 is considered to be good. Some irregularities and inaccuracies in the strip chart record were caused by the following conditions:

- Excess debris, such as trash and vegetation, accumulated in the channel, in the control and around the staff gage at times; and

- The intake pipes accumulated excess silt.

- The staff gage was situated too high in the channel so that at times of very low flow the water surface was below the bottom of the staff gage, during which time negative numbers were recorded for the water level.

The strip chart records were estimated for the following periods due to recorder malfunctions, unrecoverable records and equipment upgrading:

- May 1, 2, 3, 4, 5, 1989;

- May 9, 1989 to May 16, 1989; and

- June 11, 12, 13, 21, 1989.

4.1.2.1.6 Highline Lateral. - The continuous stage record for Water Year 1989 is considered to be good. Some irregularities and inaccuracies were caused by the following conditions:

- The use of a feeder channel instead of a stilling well, which caused an irregular trace on the strip chart record, making the stage record difficult to interpret; and

- A staff gage positioned on the weir, causing irregular flow.

The strip chart record was estimated for the following period due to a recorder malfunction:

- April 18, 1989 to April 25, 1989.

4.1.2.1.7 South Plants Ditch. - Irregularities or inaccuracies in the strip chart record are difficult to access because flow only occurred at the station on June 3 and 4, 1989.

The strip chart record was estimated for the following period due to unrecoverable records:

- May 2. 1989 to May 16, 1989.

4.1.2.1.8 South First Creek. - The continuous stage record for Water Year 1989 is considered to be good. The station simultaneously operated a Stevens Type F recorder (analog) and a Campbell Scientific CR-10 (digital) data logger. No records were estimated for this station, however, gaps in the CR-10 data logger stage record were filled in with available strip chart stage records. Some irregularities and inaccuracies were caused by the following conditions:

- Intake pipes installed too high to equilibrate the stream and stilling well at periods of very low flow, this problem affected only the analog record; and

- Excess debris, such as vegetation and trash, accumulated in the channel, in the control and around the staff gage.

4.1.2.1.9 North First Creek. - The continuous stage record for Water Year 1989 is considered to be good. The station simultaneously operated a Stevens Type F recorder (analog) and a Campbell Scientific CR-10 data logger (digital). No records were estimated for this station, however, gaps in the CR-10 data logger stage record were filled in with available strip chart stage records. Some irregularities and inaccuracies were caused by the following conditions:

- Intake pipes installed too high to equilibrate the stream and stilling well at periods of very low flow. This problem affected only the analog record; and

- Excess debris, such as vegetation and trash, accumulated in the channel, in the control and around the staff gage.

4.1.2.1.10 First Creek Off-Post. - The stage record for this station is considered inadequate because flow was observed, early in the water year, passing beneath the H-flume and the stilling well. No records were estimated for this station. A new concrete triangular-throated flume was installed in July of 1989 to correct the problem. The station was operative from July to August 1989. In August 1989 vandals broke in and stole the recording equipment rendering the station inoperative for the remainder of the water year.

4.1.2.1.11 Basin A. - The continuous stage record for Water Year 1989 is considered to be good. Some irregularities and inaccuracies were caused by the following conditions:

- Debris accumulated in the notch of the weir at times.

The strip chart record was estimated for the following period due to equipment upgrading:

- June 21, 1989.

4.1.2.2 Stage Comparison of Analog and Digital Data. Stage is measured at the monitoring stations in several ways. The long time standard, Stevens Type F recorder, is installed at all of the monitoring stations, except Havana Interceptor, at the RMA. Many of the stations have been retrofitted with new digital recorders to increase the accuracy and reliability of data acquisition and also provide ease in data reduction efforts. The digital recorders used at the continuous monitoring stations are either the Campbell Scientific CR-10 data logger or the Omnidata DP115 datapod. The stations operate simultaneously (if possible) both a Stevens Type F recorder and one of the digital recorders in order to assess the reliability and accuracy of the new equipment. A comparison of the Stevens Type F recorder data (strip chart/analog) to the Campbell Scientific CR-10 data logger (digital) data was made and is presented in this section. The DP115 datapod was not as effective a recorder as the CR-10, and a longer troubleshooting period will be needed to obtain efficient data acquisition.

The monitoring or gaging stations equipped with the CR-10 data loggers are South First Creek (SW08003), South Uvalda (SW12005), Havana Interceptor (SW11002) and North First Creek (SW24002). The stations' control on First Creek are new and began recording in early April. The stations at South Uvalda and Havana Interceptor are long standing monitoring stations and the CR-10 became operational in early April as well. This comparison analysis encompasses several weeks in the water year. The comparison analysis presented in this section focuses on a one-week period during the water year in which both the Stevens recorder and the CR-10 data logger were operational and obtaining reliable (or acceptable) good records (varietal flows). The Havana Interceptor station was not included in the comparison because the Stevens Type F recorder and its associated structures were removed from the channel prior to the installation of the CR-10. The stage data obtained from the two different types of equipment is illustrated graphically in Figures 4.1-2, 4.1-3 and 4.1-4.

4.1.2.2.1 South Uvalda (SW12005). - This station is located on the southern boundary of the Arsenal and receives a constant flow that exhibits sharp peaks during minor precipitation events.

Figure 4.1-2 shows varied response to the storms as recorded on the two recorders, related directly to the intensity of the storm. The Stevens recorder exhibits a lag in response time that may be attributed to silting of the intake pipes. The CR-10 does exhibit a quick response to the rising peak of a storm without any lag in response. The graphical comparison in Figure 4.1-2 provides a visual comparison and shows that although the Stevens recorder does pick up the rising stage, the stage is usually receding and reaching baseflow conditions by the time equilibrium in the stilling well is achieved. The two recorders functioned equally well during low flow or baseflow conditions.

4.1.2.2.2 South First Creek (SW08003). - This station is located on the southeastern boundary of the Arsenal. The stream is generally intermittent, drying up for short periods in the summer, and exhibits a noticeable response only to major storms. The Stevens Type F recorder and the Campbell Scientific CR-10 data logger were installed in early April and both recorded stage for the remainder of the water year. The graphical comparison presented in Figure 4.1-3 for this station shows a similarity in the response between the two types of equipment. The peaks were almost identical and varied only in time. The digital clock in the CR-10 is found to be a more accurate and reliable timepiece and variations in timing of recorded peak flows may be attributable to the Stevens recorder clock. The placement of the intake pipes too high above the channel bottom resulted in problems at this station and caused the Stevens recorder to show no flow when in fact there was flow. The bubbler system was able to record gage data at these lower water depths due to the bubbler line being positioned lower in the stream channel than the intake pipes. The two recorders functioned equally well during baseflow conditions.

4.1.2.2.3 North First Creek (SW24002). - This station is located near the northern boundary of the Arsenal. The stream is generally intermittent, drying up for several months in the summer, and exhibits a noticeable response only to major storms. The Stevens Type F recorder and the Campbell Scientific CR-10 data logger were installed in early April and recorded stage for the remainder of the water year. The graphical comparison presented in Figure 4.1-4 for this station shows a similarity in the response between the two types of equipment. The peaks were almost identical and varied only in time. The digital clock in the CR-10 is found to be a more accurate and reliable timepiece and variations in timing of recorded peak flows may be attributable to the Stevens recorder clock. The bubbler system was able to record gage data at lower water depths due to the bubbler line being positioned lower in the stream channel than the intake pipes. The recording of very low flow was much more of a problem at North First Creek than at South First Creek, because the Stevens recorders record showed zero flow more than one week earlier that the CR-10's record of zero flow, when in fact very low flow did exist. The two recorders functioned equally well during baseflow condition.

4.1.2.3 Rating Curves and Equations. Another component in determining the daily water discharge for the 11 monitoring stations was the conversion of stage to discharge from rating curves. The methodology for rating curve development and rating curve verification generally followed standard procedures described by U.S. Geological Survey Water Supply Paper 2175 (Rantz, 1982). The rating curves for the 11 continuous-recording surface-water gaging stations at RMA represent a wide variety of hydraulic structures with varying degrees of sensitivity to low and high flow conditions. They also represent a wide variety of section, channel or compound controls with large variations in hydraulic behavior at various stages and streamflow conditions. The rating curves presented in Appendix A-3 represent the combination of structure hydraulics, station controls and streamflow conditions found at RMA. Rating equations were developed to describe mathematically the straight-line segments of each rating curve and are presented in Appendix A-4.

The rating curves for each of the gaging stations at RMA have varying degrees of accuracy for the defined and extrapolated regions, primarily because of the structures complex hydraulic behavior at certain stages or the lack of verifiable instantaneous discharge and staff measurements at high and/or very low flows. All gaging stations except Havana Interceptor have structures which control the water surface profile upstream of the station. Each rating equation therefore has a unique characteristic curve that represents the combined factors of channel geometry, channel bed conditions, bank geometry and channel approach conditions, artificial structure size and type, and streamflow conditions.

Three types of rating curves were developed for the surface-water gaging stations at RMA. These types include:

1. Empirically derived rating curves based on instantaneous discharge and staff measurements made in the field during the 1988 and 1989 water years. Verified instantaneous measurements made during Water Years 1988 and 1989 monitoring programs and verified measurements made in 1986 and 1987 were used to help develop empirical rating curves. Empirically derived rating curves were defined for the South First Creek (SW08003), South Uvalda (SW12005), North Uvalda (SW01001), Highline Lateral (SW12007), North First Creek (SW24002) and Peoria Interceptor (SW11001) monitoring stations.

2. Theoretical rating curves were developed for channels with no verifiable instantaneous discharge and staff measurements and for channels that exhibit strict channel control. A theoretical rating curve was developed for Havana Interceptor

(SW11002) using the U.S. Army Corps of Engineers Water Surface Profile model, HEC-2 (U.S. Army Corps of Engineers, 1982).

3. Empirical laboratory-defined rating curves were used for all structures on RMA for which no verified instantaneous discharge and staff measurements were available. These stations included Ladora Weir (SW02001), South Plants Ditch (SW01003), Basin A (SW36001), and First Creek Off-Post (SW37001).

Several structure types are currently in place at RMA to monitor surface water. The type of structure at each surface-water gaging station, along with present channel geometry and channel conditions (roughness, slope, vegetation, etc.) affects the type and accuracy of each rating equation. Channel geometry and channel condition define the relationship between stage and discharge for stations that do not have laboratory-defined empirical rating equations and is outlined in Section 3.0. Structure, channel control, and rating curve types for each station are described in Table 4.1-2.

4.1.2.3.1 Havana Interceptor. - The previously developed rating curve for Havana Interceptor used the HEC-2 model to predict gage heights and corresponding discharges from channel geometry. This method of determining the stage-discharge relationship was considered best as limited verifiable instantaneous discharge and staff measurements were available for empirical rating curve development. Two verified instantaneous discharge measurements made during Water Year 1989 were used to confirm the permanence of the rating (Appendix A-2.3). Additionally, field observations indicated some backwatering did occur at this station during part of the 1989 water year. A rating shift was developed for the period of backwatering as indicated by current meter measurement. Both the rating curve and the rating shift are considered to be fair.

4.1.2.3.2 Peoria Interceptor. - The rating curve for the Peoria Interceptor structure for the beginning part of Water Year 1989 was previously derived and was based on field measurements of instantaneous discharge and corresponding staff measurements. No instantaneous discharge and staff measurements were available to confirm the permanence of the rating curve during this period of the water year. The Peoria Interceptor structure consisted of a flat-crested weir constructed out of a narrow plank positioned perpendicular to flow and embedded into the banks on both sides of the channel. During Water Year 1989, a V-notch was cut in the existing wood plank and a 90° V-notch steel plate was attached to the wooden control structure. The stage-discharge relationship for the modified control structure on Peoria Interceptor was developed using the empirical laboratory rating for a 90° V-notch weir. None of the three available instantaneous

Table 4.1-2 Surface-Water Structures, Channel Control and Rating Curves

Station	Structure	Control	Rating
Irondale Gulch Drainage Basin			
Havana Interceptor	Concrete-lined Channel	Channel	Theoretical
Peoria Interceptor	90° V-notch Weir Plate/Sharp-crested	Section	Empirical
Ladora Weir	Standard Suppressed Rectangular Weir	Section	Empirical-Laboratory
South Uvalda	Broad-crested Weir with V-notch	Compound	Empirical
North Uvalda	Broad-crested Weir with V-notch	Compound	Empirical
Highline Lateral	Cipolletti Weir	Section	Empirical
South Plants Ditch	90° V-notch Weir Plate/Sharp-crested Suppressed Rectangular Weir	Section	Empirical-Laboratory
First Creek Drainage Basin			
South First Creek	V-notch concrete weir	Section	Empirical
North First Creek	V-notch concrete weir	Section	Empirical
First Creek Off-Post	Concrete Triangular-throated flume	Section	Empirical-Laboratory
South Platte Drainage Basin			
Basin A	90° V-notch Weir Plate	Section	Empirical-Laboratory

discharge measurements provided reliable information to allow verification of the laboratory rating. For flows with water depths greater than the maximum flow through the V-notch, the previously defined rating curve was adjusted by adding the maximum flow through the V-notch to each of the previously defined discharge and corresponding gage height values. Since no discharge measurements were available, the rating curve is considered fair in both the defined and extrapolated regions. However, high water levels in Havana Pond creates backwater in the Peoria Interceptor channel when the pond is filled, and submergence occurs over the Peoria Interceptor structure. No rating has been derived for this flow condition and flow values were estimated. The two rating curves for Peoria Interceptor with corresponding valid periods are presented in Appendix A-3.

4.1.2.3.3 Ladora Weir. - The stage-discharge relationship for Ladora Weir was previously developed using the empirical laboratory rating for a six-foot standard suppressed rectangular weir (Appendix A-3). No instantaneous discharge measurements were made during Water Year 1989 to confirm the permanence of the rating or to allow any adjustments to be made to the rating. The rating curve is considered fair, when the head is at least 0.20 feet above the weir crest to prevent the nappe from clinging to the crest (Bureau of Reclamation, 1974). Note that flow with heads less than 0.20 feet can only be estimated.

4.1.2.3.4 South Uvalda. - The rating curve for the South Uvalda structure was previously derived, based on field measurements of instantaneous discharge and corresponding staff measurements. The South Uvalda structure is a compound broad-crested weir with a V-notch. Three verified instantaneous discharge and staff measurements, made prior to a runoff event in May 1989, confirmed the permanence of the rating curve. However, two verified instantaneous discharge and staff measurements, made after the runoff event in May 1989, indicated a shift in the rating curve due to scouring of the channel during the runoff event. The two rating curves for South Uvalda with corresponding valid periods are presented in Appendix A-3. Both rating curves are considered to be fair, both in the defined and extrapolated regions.

4.1.2.3.5 North Uvalda. - The rating curve for the North Uvalda structure was previously derived, based on field measurements of instantaneous discharge and corresponding staff measurements (Appendix A-3). The North Uvalda structure is a compound broad-crested weir with a V-notch. No instantaneous discharge measurements were made during Water Year 1989 to confirm the permanence of the rating or to allow any adjustments to be made to the rating. The rating curve is considered fair, both in the defined and extrapolated regions.

4.1.2.3.6 Highline Lateral. - The rating curve for the Highline Lateral structure was previously derived, based on field measurements of instantaneous discharge and corresponding staff measurements (Appendix A-3). The Highline Lateral structure is a six-foot Cipolletti Weir. The Cipolletti Weir laboratory rating equation was not used because of significant approach velocities and because a staff gage is welded to the weir blade within the flow field. No instantaneous discharge measurements were made during Water Year 1989 to confirm the permanence of the rating or to allow any adjustments to be made to the rating. The rating curve is considered fair, both in the defined and extrapolated regions.

4.1.2.3.7 South Plants Ditch. - The rating curve for South Plants Ditch was previously developed using a combination of the empirical laboratory ratings for a 90° V-notch weir and a sharp-crested suppressed rectangular weir. No instantaneous discharge measurements were made during Water Year 1989 to confirm the permanence of the rating or to allow any adjustments to be made to the rating due to the lack of flow at this station. The rating curve is considered poor, both in the defined and extrapolated regions.

4.1.2.3.8 South First Creek. - The rating curve for the South First Creek structure was empirically derived, based on field measurements of instantaneous discharge and corresponding staff measurements. The South First Creek structure is a compound concrete weir with a V-notch. The empirical stage-discharge relationship was developed using eight verified instantaneous discharge measurements. The rating curve is considered good in the defined region and fair in the extrapolated regions.

4.1.2.3.9 North First Creek. - The rating curve for North First Creek was empirically derived, based on field measurements of instantaneous discharge and corresponding staff measurements. The North First Creek structure is a compound concrete weir with a V-notch. The empirical stage-discharge relationship was developed using one verified instantaneous discharge measurement in combination with a HEC-2 analysis. The rating curve is considered fair, both in the defined and extrapolated regions.

4.1.2.3.10 First Creek Off-Post. - The stage-discharge relationship for First Creek Off-Post was developed using the empirical laboratory rating for a triangular-throated flume with 3:1 sloping sidewalls in the throat. The one instantaneous discharge measurement made after the structure was installed provided reliable information in extrapolating the rating for flow below the laboratory rating. The rating curve is considered fair, in both the defined and extrapolated regions.

4.1.2.3.11 Basin A. - The stage-discharge relationship for Basin A was developed using the empirical laboratory rating for a 90° V-notch weir. No instantaneous discharge measurements were made during Water Year 1989 to confirm the permanence of the rating or to allow any adjustments to be made to the rating. The rating curve is considered fair, when the head is greater than 0.20 feet above the V-notch and the nape is prevented from clinging to the crest (BLM, 1974). Note that flows with heads less than 0.20 feet can only be estimated.

None of the rating curves or equations for the laboratory-defined empirically rated structures exceed the capacity of the structure. High flows for all other rating curves were determined by applying Manning's equation to the highest known gage height for a given station during Water Year 1989 and using the most recent cross section survey data.

4.1.3 Surface-Water Hydrologic Conditions

This section discusses the water discharge records for the 11 continuous-recording stations. Mean daily, minimum daily and maximum daily discharge flows and total monthly streamflow are presented in this section. Water-discharge records for the 11 continuous-recording surface-water gaging stations are presented in Appendix A-8. Annual hydrographs of total monthly streamflow are shown in Figures 4.1-5 to 4.1-15. Annual hydrographs of mean daily discharges are shown in Figure 4.1-16 to 4.1-26.

Surface water at RMA originates from 3 direct sources. These sources are direct precipitation as rain or snow and subsequent runoff, inflow from drainage basins off-post, and ground water that contributes to baseflow. The predominant sources of surface water at the 11 continuous-recording surface-water gaging stations are shown in Table 4.1-3.

Drainage areas typically can be described as: (1) urban, (2) natural watershed, or (3) in-channel (direct) contribution. Drainage areas range from 0.066 sq mi (35.2 acres) to 36.70 sq mi (23,488 acres). Drainage boundaries for RMA gaging stations are shown on Plates 1.3-1 and 2.3-1 and in Figures 2.3-2 and 2.3-3.

The majority of the streams on RMA are intermittent and streamflow occurs in response to urban runoff, released or diverted flow, or direct precipitation. Perennial streams include First Creek and Uvalda Interceptor. The First Creek channel and drainage basin crosses RMA by entering the property at Section 8 and exiting it near the North Bog in Section 24. Field observations and gain/loss studies indicated that First Creek can be either a gaining (effluent) or losing (influent) stream

Table 4.1-3 Surface-Water Sources at Continuous-recording Stations

Station	Primary Source of Surface-water	Secondary Source of Surface-water
Irondale Gulch Drainage Basin		
Havana Interceptor	Urban Runoff	Direct Precipitation
Peoria Interceptor	Urban Runoff	Direct Precipitation
Ladora Weir	Controlled Outflow from Lower Derby Lake	None
South Uvalda	Baseflow (ground-water inflow)	Urban Runoff/Direct Precipitation
North Uvalda	Controlled Flow from Highline Lateral and/or South Uvalda	Urban Runoff/Direct Precipitation
Highline Lateral	Controlled Flow from South Platte	None
South Plants Ditch	Watershed Runoff	None
First Creek Drainage Basin		
South First Creek	Baseflow (ground-water inflow)	Watershed Runoff/Direct Precipitation
North First Creek	Baseflow (ground-water inflow)	Watershed Runoff/Direct Precipitation
First Creek Off-Post	Baseflow (ground-water inflow)	Watershed Runoff
South Platte Drainage Basin		
Basin A	Baseflow (ground-water inflow)	Watershed Runoff

as it crosses RMA. The variation in streamflow conditions depends on soil and channel bank saturation and on recharge to the near-surface ground-water system at different times of the year.

First Creek also has several small tributaries on RMA that can contribute a small portion to the stream flow during snowmelt runoff or heavy rainfall events. Field observations and surface-water data further indicate that for most years significantly less surface-water leaves RMA near North First Creek station than enters at the South Boundary. Based on the information available for Water Year 1989, First Creek would be characterized as a losing (influent) stream.

Uvalda Interceptor is the only other perennial stream at RMA. Uvalda Interceptor is in the Irondale Gulch drainage basin and is a man-made channel that is deep enough to intercept the near-surface ground water. Streamflow at the South Uvalda gaging station can increase quickly from baseflow conditions in response to precipitation occurring on the urbanized areas of the drainage basin. The South Uvalda gaging station is near the southern boundary of RMA at 56th Street. The Uvalda Interceptor flows in a northerly direction to Sixth Avenue, where it is diverted to either Upper or Lower Derby Lake.

Havana Interceptor and Peoria Interceptor are in the Irondale Gulch drainage basin and primarily receive urban runoff and are intermittent in nature. The drainage area of the Peoria Interceptor is small (0.644 sq mi) and nearly 100 percent is urbanized. Havana Interceptor has approximately 2.6 sq mi of urbanized area and a total drainage area of 5.22 sq mi.

All other stations on RMA -- Ladora Weir, North Uvalda, Highline Lateral, South Plants Ditch and Basin A -- respond to direct precipitation, diversion of streamflow, or controlled releases from lakes or the South Platte River on RMA. All of these stations are in the Irondale Gulch drainage basin except Basin A which is in the South Platte drainage basin.

Most precipitation occurring on RMA does not contribute to surface-water runoff in stream channels, because of poorly defined tributary drainage and channels that are bermed on one or both sides. The result is that a majority of the precipitation occurring on RMA infiltrates into the ground.

4.1.3.1 Streamflow Characteristics and Extremes. Continuous-recording surface-water gaging stations located on drainages without diversions and inflows from controlled releases exhibit flow conditions typical for this area of Colorado, with maximum monthly flows occurring in May and July 1989 as the result of snowmelt runoff, thunderstorms and/or multi-day rainfall events. Minimum monthly flows occurred in March 1989, and could be expected to be even lower during the winter months for which there is no record. Field observations indicate that low flow or no flow conditions occurred during the winter months. Continuous-recording surface-water gaging stations that do not have controlled flow conditions include Havana Interceptor, Peoria Interceptor, South Uvalda, South First Creek, North First Creek, South Plants Ditch, Basin A and First Creek Off-Post. Continuous-recording surface-water gaging stations with controlled flow include: Ladora Weir, which has controlled flow from Lower Derby Lake, North Uvalda, which is mostly controlled by diversion from the South Platte River through the Highline Lateral canal and by a small portion of annual flow diverted from the Uvalda Interceptor.

4.1.3.1.1 Havana Interceptor. - Havana Interceptor receives runoff from approximately 5.22 sq mi, of which 2.6 sq mi is comprised of storm sewer drainage. Figure 4.1-5 presents the monthly total runoff for Havana Interceptor. The maximum monthly runoff of 183 ac-ft (0.65 in over the entire 5.22 sq mi drainage area) occurred in July 1989. The minimum monthly runoff for the available record was 12 ac-ft (0.04 in) in November 1988. The maximum monthly runoff was approximately 15 times greater than the minimum monthly runoff.

4.1.3.1.2 Peoria Interceptor. - Peoria Interceptor drains an urbanized area of approximately 0.644 sq mi. The monthly total runoff for Peoria Interceptor is presented in Figure 4.1-6. The maximum monthly runoff of 72 ac-ft (2.09 in over the entire 0.644 sq mi drainage area) occurred in June 1989. The minimum monthly runoff for the available record was 11 ac-ft (0.32 in) in November 1988. The maximum monthly runoff was approximately 6.5 times greater than the minimum monthly runoff.

4.1.3.1.3 Ladora Weir. - Surface-water flow at Ladora Weir is controlled by releases from Lower Derby Lake. For this reason, specific analysis of streamflow trends, maximum or minimum flow, or runoff depths is not meaningful. Figure 4.1-7 presents the total monthly flow that was passed through Ladora Weir from Lower Derby Lake.

4.1.3.1.4 South Uvalda. - South Uvalda receives runoff from approximately 7.72 sq mi, of which 4.12 sq mi is comprised of storm sewer drainage. Figure 4.1-8 presents the monthly total runoff for South Uvalda. The maximum monthly runoff of 102 ac-ft (0.23 inches over the entire 7.72 sq mi drainage area) occurred in July 1989. The minimum monthly runoff for the available record was 23 ac-ft (0.05 in) in November 1988. The maximum monthly runoff was approximately 4 times greater than the minimum monthly runoff.

4.1.3.1.5 North Uvalda. - Streamflow at the North Uvalda gage is controlled by a diversion located on the Uvalda Interceptor approximately 150 ft upstream of North Uvalda gage. Large flow events are usually associated with streamflow diverted from Highline Lateral canal as a result of water diverted into Highline from the South Platte River. As the majority of flows occurring at the North Uvalda gage are controlled by the diversion, analysis of streamflow trends, maximum or minimum flows, or runoff depths is not meaningful. The total monthly flow that was passed through North Uvalda station is presented in Figure 4.1-9.

4.1.3.1.6 Highline Lateral. - Streamflow in Highline Lateral canal is controlled by diversion at the South Platte River. As streamflow in the Highline Lateral canal is controlled, analysis of runoff trends, maximum or minimum flows, or runoff depths is not meaningful. The total monthly flow for Highline Lateral is presented in Figure 4.1-10.

4.1.3.1.7 South Plants Ditch. - The South Plants Ditch gaging station receives runoff from approximately 0.055 sq mi of storm sewer drainage from the South Plants area. Monthly total runoff for South Plants Ditch is presented in Figure 4.1-11. Analysis of the recorded gage data indicates that flow occurred on only June 3 - 4, 1989.

4.1.3.1.8 South First Creek. - The surface drainage for South First Creek station is 26.38 sq mi, with only a very small portion that is urbanized. Figure 4.1-12 presents South First Creek station total monthly runoff. The maximum monthly runoff of 95 ac-ft (0.07 inches over the entire 26.38 sq mi drainage area) occurred in May 1989. The minimum monthly runoff for the available record was 6 ac-ft (0.004 in) in September 1989. The maximum monthly runoff was approximately 15 times greater than the minimum monthly runoff.

4.1.3.1.9 North First Creek. - The surface drainage for North First Creek station is 36.70 sq mi. This station was put into operation in April, 1989. Figure 4.1-13 presents North First Creek station total monthly runoff. The maximum monthly runoff of 76 ac-ft (0.04 in over the entire 36.70 sq mi drainage area) occurred in May 1989. The minimum monthly runoff of 35 ac-ft (0.02 in) was recorded in April 1989. Analysis of the recorded gage data indicates that no flow occurred during July, August, and September 1989.

4.1.3.1.10 First Creek Off-Post. - The station receives streamflow that exits the north boundary of the RMA at 96th Avenue. Figure 4.1-14 presents First Creek Off-Post station total monthly runoff. The station was rendered inoperative for most of Water Year 1989 because of high amounts of flow passing beneath the old flume. The new flume began operation in early July and kept records until early August when vandals broke in and stole equipment, thus rendering the station inoperative.

4.1.3.1.11 Basin A. - The Basin A gage receives mostly storm sewer drainage from approximately 0.055 sq mi of the South Plants area and some natural drainage from north of the South Plants area. Figure 4.1.15 presents monthly total runoff for Basin A. The maximum monthly runoff of .67 ac-ft (0.23 in over the entire 0.055 sq mi drainage area) occurred in June 1989. Analysis of the recorded gage data indicates that very small flows occurred during most of the water year; however, flows less than 0.005 cfs (4.5 gpm) but greater than 0.00 cfs are recorded as trace (T).

4.1.3.1.12 Streamflow Inflow/Outflow Comparison. - Surface inflow from off-post sources enters RMA and passes through the Highline Lateral, South First Creek, South Uvalda, Peoria Interceptor and Havana Interceptor monitoring stations. A summary of monthly volumes entering RMA from these sources is provided in Table 4.1-4. The inflow sources encompass a total drainage area of 36 sq mi, not including the Highline Lateral drainage area. The maximum monthly surface inflow volume of 688 ac-ft occurred in May 1989. The minimum monthly inflow volume was 116 ac-ft and occurred in April 1989.

Outflow leaves the RMA is measured and passes through the Sewage Treatment Plant and North First Creek monitoring stations. A summary of monthly surface outflow volumes is presented in Table 4.1-4. A maximum outflow volume of 77 ac-ft was recorded in May 1989 with a minimum outflow volume of 2 ac-ft in July 1989. Figure 4.1-27 illustrates a comparison of inflow and outflow volumes for April through September 1989.

4.1.3.2 Annual Streamflow Analysis. During Water Year 1989, streamflow period of records varied between stations due to station relocations or station renovations. For the period of recorded streamflow, instantaneous peak and mean peak discharges for stations located on drainages without diversions and inflows from controlled releases occurred at various times during the spring and early summer of 1989. The instantaneous peak and mean peak flow at the South First Creek Station occurred in May 1989. North First Creek, Basin A, and South Plants Ditch took place in June 1989 with South Uvalda, First Creek Off-Post, and Havana Interceptor stations not occurring until early July 1989. The mean daily peak at the Peoria Interceptor station was in June and the instantaneous peak was in July. Minimal streamflows occurred during the winter months based on field observations. In general, streamflows increased during the spring in response to thawing, increased precipitation and snowmelt runoff. Streamflows peaked during late spring and early summer when soil saturation in the respective drainages was highest and long duration precipitation events were common. Streamflows generally decreased throughout the summer and fall, as soil moisture was depleted from evapotranspiration, coupled with a decrease in the frequency and amount of precipitation. Thunderstorm events occurring in the summer and fall months caused peaks in daily hydrographs, but did not cause a discernable increase in mean monthly discharge.

Table 4.1-4 Summary of RMA Inflow and Outflow Volumes

Summary of Monthly Inflow Volume from Off-Post Sources (ac-ft)

	Station						
Month	Highline Lateral	South First Creek	South Uvalda	Peoria Interceptor	Havana Inteceptor	Total	Cumulative Total
April	0.00	42.73*	28.96*	21.26*	23.40*	116.35	116.35
May	378.05	95.23	98.96	61.69	53.82*	687.75	804.10
June	54.74	81.52	82.45	72.20	146.44	437.35	1241.45
July	0.00	12.87	102.35	35.59	182.97	333.78	1575.23
August	28.20	24.40	64.30	22.37	53.45	192.72	1767.95
September	0.00	6.27	62.42	61.92	81.52	212.13	1980.08
TOTAL	460.99	263.02	439.44	275.03	541.60	1980.08	

Summary of Monthly Outflow Volume Leaving RMA (ac-ft)

	Station			
Month	Sewage Treatment Plant	North First Creek	Total	Cumulative Total
April	0.36	34.62*	34.98	34.98
May	1.02	76.11	77.13	112.11
June	1.16	70.59	71.75	183.86
July	2.00	0.00	2.00	185.86
August	2.62	0.00	2.62	188.48
September	1.79	0.00	1.79	190.27
TOTAL	8.95	181.32	190.27	

* Partial month only

4.1.3.3 Mean Monthly, Maximum Daily and Minimum Daily Flows. Mean monthly, maximum daily, and minimum daily flows are summarized at the bottom of the water-discharge records in Appendix A-8. Annual plots of these values by month are shown for each station in Figures 4.1-28 to 4.1-38. The streams on RMA exhibit large streamflow variations on a monthly and daily basis. For all stations that do not have controlled flow, the mean monthly flows were highest in spring and early summer 1989. In many cases, maximum daily flows were an order of magnitude greater than mean monthly flows and minimum daily flow. This indicates that the maximum high flow events are of short duration and contribute only a small percentage to the mean monthly discharge.

Instantaneous peak discharges for stations without controlled flow ranged from 0.52 cfs at Basin A to 1570 cfs at Havana Interceptor. Instantaneous peak discharges, mean monthly, maximum daily, and minimum daily flows are summarized in Table 4.1-5. In general, during runoff events, instantaneous discharges ranged from almost equal to 22 times the maximum daily flows for the same day. The stations with controlled flow (Ladora Weir, North Uvalda, Highline Lateral) exhibit patterns which are not related to watershed response and/or natural flow conditions.

A station-by-station descriptive summary of minimum daily, maximum daily, and mean monthly flows follows:

4.1.3.3.1 Havana Interceptor. - Mean monthly, maximum daily, and minimum daily discharges are presented in Figure 4.1-28. Minimum daily flows for each month were less than 0.65 cfs. Maximum daily flows for each month ranged from 0.43 cfs in October 1988 to 71 cfs in July 1989. The mean monthly flows ranged from 0.26 cfs in November 1988 to 2.98 cfs in July 1989.

4.1.3.3.2 Peoria Interceptor. - Mean monthly, maximum daily, and minimum daily discharges are presented in Figure 4.1-29. Minimum daily flows for each month were less than 0.15 cfs. Maximum daily flows for each month ranged from 0.95 cfs in October 1988 to 19 cfs in June 1989. Mean monthly flows ranged form 0.19 cfs in November 1988 to 1.21 cfs in June 1989.

4.1.3.3.3 Ladora Weir. - Mean monthly, maximum daily, and minimum daily discharges are presented in Figure 4.1-30. The Ladora Weir gaging station receives controlled flow from Lower Derby Lake. Minimum daily flows for each month were less than 0.11 cfs. Maximum daily flows for each month ranged from 0.00 cfs in May and June 1989 to 13 cfs in July 1989. Mean monthly flows ranged from 0.0 cfs in May and June 1989 to 1.1 cfs in July 1989.

Table 4.1-5 Summary of Daily Minimum and Maximum Discharges, Instantaneous Minimum and Maximum Discharges and Mean Daily Discharge for Each Month of Record, Water Year 1989

Station	Daily Minimum Discharge (cfs)	Instantaneous Minimum Discharge (cfs)	Daily Maximum Discharge (cfs)	Instantaneous Maximum Discharge (cfs)	Mean Daily Discharge (cfs)
			October 1988		
Havana Interceptor	0.22	0.19	0.43	0.74	0.33
Peoria Interceptor	0.00	0.00	0.95	3.4	0.39
Ladora Weir	0.11	0.11	2.1	5.3	0.23
South Uvalda	0.35	0.30	0.54	0.94	0.43
North Uvalda	0.11	0.11	0.14	0.14	0.13
Highline Lateral	0.00	0.00	21	109	3.2
South First Creek	NR	NR	NR	NR	NR
North First Creek	NR	NR	NR	NR	NR
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	TR	0.00	TR	TR	TR
First Creek Off	NR	NR	NR	NR	NR
			November 1988		
Havana Interceptor	0.17	0.17	0.76	6.1	0.26
Peoria Interceptor	0.00	0.00	2.4	11	0.39
Ladora Weir	0.00	0.06	0.11	0.11	0.05
South Uvalda	0.30	0.27	1.2	6.1	0.41
North Uvalda	0.11	0.11	0.12	0.12	0.12
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South First Creek	NR	NR	NR	NR	NR
North First Creek	NR	NR	NR	NR	NR
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	TR	0.00	TR	0.02	TR
First Creek Off	NR	NR	NR	NR	NR
			December 1988		
Havana Interceptor	NR	NR	NR	NR	NR
Peoria Interceptor	NR	NR	NR	NR	NR
Ladora Weir	NR	NR	NR	NR	NR
South Uvalda	NR	NR	NR	NR	NR
North Uvalda	NR	NR	NR	NR	NR
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South First Creek	NR	NR	NR	NR	NR
North First Creek	NR	NR	NR	NR	NR
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	NR	NR	NR	NR	NR
First Creek Off	NR	NR	NR	NR	NR

Table 4.1-5 Summary of Daily Minimum and Maximum Discharges, Instantaneous Minimum and Maximum Discharges and Mean Daily Discharge for Each Month of Record, Water Year 1989 (continued)

Station	Daily Minimum Discharge (cfs)	Instantaneous Minimum Discharge (cfs)	Daily Maximum Discharge (cfs)	Instantaneous Maximum Discharge (cfs)	Mean Daily Discharge (cfs)
			January 1989		
Havana Interceptor	NR	NR	NR	NR	NR
Peoria Interceptor	NR	NR	NR	NR	NR
Ladora Weir	NR	NR	NR	NR	NR
South Uvalda	NR	NR	NR	NR	NR
North Uvalda	NR	NR	NR	NR	NR
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South First Creek	NR	NR	NR	NR	NR
North First Creek	NR	NR	NR	NR	NR
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	NR	NR	NR	NR	NR
First Creek Off	NR	NR	NR	NR	NR
			February 1989		
Havana Interceptor	0.23	0.22	0.23	0.24	0.23
Peoria Interceptor	0.11	0.00	0.11	0.62	0.11
Ladora Weir	NR	NR	NR	NR	NR
South Uvalda	NR	NR	NR	NR	NR
North Uvalda	NR	NR	NR	NR	NR
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South First Creek	NR	NR	NR	NR	NR
North First Creek	NR	NR	NR	NR	NR
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	NR	NR	NR	NR	NR
First Creek Off	NR	NR	NR	NR	NR
			March 1989		
Havana Interceptor	0.21	0.19	1.5	2.5	0.38
Peoria Interceptor	0.00	0.00	1.2	6.2	0.36
Ladora Weir	NR	NR	NR	NR	NR
South Uvalda	0.27	0.27	0.33	0.42	0.31
North Uvalda	NR	NR	NR	NR	NR
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South First Creek	NR	NR	NR	NR	NR
North First Creek	NR	NR	NR	NR	NR
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	TR	TR	TR	TR	TR
First Creek Off	NR	NR	NR	NR	NR

Table 4.1-5 Summary of Daily Minimum and Maximum Discharges, Instantaneous Minimum and Maximum Discharges and Mean Daily Discharge for Each Month of Record, Water Year 1989 (continued)

Station	Daily Minimum Discharge (cfs)	Instantaneous Minimum Discharge (cfs)	Daily Maximum Discharge (cfs)	Instantaneous Maximum Discharge (cfs)	Mean Daily Discharge (cfs)
April 1989					
Havana Interceptor	0.63	0.43	5.4	15.	1.3
Peoria Interceptor	0.02	0.00	3.8	12.	0.54
Ladora Weir	NR	NR	NR	NR	NR
South Uvalda	0.22	0.17	3.9	26	0.49
North Uvalda	NR	NR	NR	NR	NR
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South First Creek	0.65	0.63	1.5	1.9	0.86
North First Creek	0.47	0.44	1.2	1.5	0.70
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	TR	0.00	TR	0.01	TR
First Creek Off	NR	NR	NR	NR	NR
May 1989					
Havana Interceptor	0.26	0.11	12	81	1.4
Peoria Interceptor	0.05	0.02	6.0	41	1.0
Ladora Weir	0.00	0.00	0.00	0.00	0.00
South Uvalda	0.23	0.22	10	151	1.6
North Uvalda	0.00	0.00	65	232	2.3
Highline Lateral	0.00	0.00	22	23	6.2
South First Creek	0.81	0.71	5.6	11	1.5
North First Creek	0.40	0.34	3.6	6.9	1.2
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	TR	0.00	0.09	0.45	0.01
First Creek Off	NR	NR	NR	NR	NR
June 1989					
Havana Interceptor	0.26	0.11	36	946	2.5
Peoria Interceptor	0.07	0.06	19	45	1.2
Ladora Weir	0.00	0.00	0.00	0.00	0.00
South Uvalda	0.59	0.19	9.6	110	1.4
North Uvalda	0.00	0.00	80	208	4.3
Highline Lateral	0.00	0.00	18	21	0.92
South First Creek	0.56	0.50	3.1	5.5	1.4
North First Creek	0.00	0.00	4.0	7.5	1.2
South Plants Ditch	0.00	0.00	0.38	1.8	0.01
Basin A	TR	0.00	0.12	0.52	0.01
First Creek Off	NR	NR	NR	NR	NR

Table 4.1-5 Summary of Daily Minimum and Maximum Discharges, Instantaneous Minimum and Maximum Discharges and Mean Daily Discharge for Each Month of Record, Water Year 1989 (continued)

Station	Daily Minimum Discharge (cfs)	Instantaneous Minimum Discharge (cfs)	Daily Maximum Discharge (cfs)	Instantaneous Maximum Discharge (cfs)	Mean Daily Discharge (cfs)
July 1989					
Havana Interceptor	0.46	0.19	71	1573	3.0
Peoria Interceptor	0.13	0.07	8.7	51	0.58
Ladora Weir	0.00	0.00	13	14	1.1
South Uvalda	0.66	0.31	20	200	1.7
North Uvalda	0.00	0.00	0.00	0.00	0.00
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South First Creek	0.00	0.00	2.1	5.0	0.21
North First Creek	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	TR	0.00	0.05	0.21	TR
First Creek Off	0.00	0.00	0.03	0.04	0.01
August 1989					
Havana Interceptor	0.37	0.13	4.1	86	0.87
Peoria Interceptor	0.05	0.02	2.6	27	0.36
Ladora Weir	0.02	0.02	0.11	0.11	0.07
South Uvalda	0.45	0.16	9.4	152	1.0
North Uvalda	0.00	0.00	0.08	0.08	0.03
Highline Lateral	0.00	0.00	7.2	10	0.46
South First Creek	0.00	0.00	3.4	7.2	0.40
North First Creek	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	TR	0.00	TR	TR	TR
First Creek Off	0.00	0.00	0.00	0.00	0.00
September 1989					
Havana Interceptor	0.32	0.19	7.0	124	1.4
Peoria Interceptor	0.11	0.05	6.2	28	1.0
Ladora Weir	0.00	0.00	0.06	0.06	0.04
South Uvalda	0.41	0.24	5.5	122	1.0
North Uvalda	0.00	0.00	0.06	0.06	0.05
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South First Creek	0.00	0.00	0.56	1.2	0.11
North First Creek	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
Basin A	TR	0.00	0.01	0.02	TR
First Creek Off	NR	NR	NR	NR	NR

4.1.3.3.4 South Uvalda. - Mean monthly, maximum daily and minimum daily discharges are presented in Figure 4.1-31. Minimum daily flows for each month were less than 0.70 cfs. Maximum daily flows for each month ranged from 0.54 cfs in October 1988 to 20 cfs in July 1989. Mean monthly flows ranged from 0.41 cfs in November 1988 to 1.7 cfs in July 1989.

4.1.3.3.5 North Uvalda. - Mean monthly, maximum daily, and minimum daily discharges are presented in Figure 4.1-32. The North Uvalda gaging station receives controlled flow from Highline Lateral for the Uvalda Interceptor. Minimum daily flows for each month were less than 0.11 cfs. Maximum daily flows for each month ranged from 0.00 cfs in July 1989 to 80 cfs in June 1989. Mean monthly flows ranged from 0.00 cfs in July 1989 to 4.3 cfs in June 1989.

4.1.3.3.6 Highline Lateral. - Mean monthly daily, and minimum daily discharges are presented in Figure 4.1-33. Highline Lateral receives controlled flow from diversions on the South Platte River. Minimum daily flows for each month were 0.00 cfs. Maximum daily flows for each month ranged from 0.00 cfs in several months to 22 cfs in May 1989. Mean monthly flows ranged from 0.00 cfs in several months to 6.2 cfs in May 1989.

4.1.3.3.7 South Plants Ditch. - Mean monthly, maximum daily, and minimum daily discharges are presented in Figure 4.1-34. Minimum and maximum daily flows and mean monthly flows were 0.00 cfs for all months except for June 1989 when the maximum daily flow was 0.38 cfs and the mean monthly flow was 0.01 cfs. Stage data indicate that flow occurred on June 3 and 4, 1989; however, as daily flow is reported to the nearest 0.01 cfs (4.5 gpm), many low flow days show as zero flow.

4.1.3.3.8 South First Creek. - Mean monthly, maximum daily, and minimum daily discharges are presented in Figure 4.1-35. Minimum daily flows for each month were less than 0.85 cfs, and zero flow occurred for several days during the 1989 water year. Maximum daily flows ranged from 0.56 cfs in September 1989 to 5.6 cfs in May 1989. Mean monthly flows ranged from 0.11 cfs in September 1989 to 1.5 cfs in May 1989.

4.1.3.3.9 North First Creek. - Mean monthly, maximum daily, and minimum daily discharges are presented in Figure 4.1-36. Minimum daily flows were less than 0.50 cfs and zero flow occurred for several days during the 1989 water year. Maximum daily flows ranged from 0.00 cfs in July, August, and September 1989 to 4.0 cfs in June 1989. Mean monthly flows ranged from 0.00 in July, August, and September 1989 to 1.2 cfs in May and June 1989.

4.1.3.3.10 First Creek Off-Post. - Mean monthly, maximum daily, and minimum daily discharges are presented in Figure 4.1-37. The First Creek Off-Post gaging station was rendered inoperative most of Water Year 1989 because of high amount of flow passing beneath the old flume. A new flume began operating in early July until early August when the equipment was destroyed by vandals. Minimum daily flows for July 1989 were 0.00 cfs. Maximum daily flows for July 1989 were 0.03 cfs. Mean months flows for July 1989 were 0.01 cfs. No other records are available for First Creek Off-Post.

4.1.3.3.11 Basin A. - Mean monthly, maximum daily, and minimum daily discharges are presented in Figure 4.1-38. Minimum daily flows for each month were reported as a trace. Maximum daily flows for each month ranged from a trace in October and November 1988, and March, April and August 1989. Mean monthly flows were a trace for all months except May and June 1989. The stage data indicates that low flow occurred for many days and were reported as 0.00 cfs in Appendix A-7. Since daily flow is reported to the nearest 0.01 cfs (4.5 gpm), many days which show zero flow have flow less than 4.5 gpm but greater than 0.00 cfs.

Diurnal fluctuations in streamflow were observed for South Uvalda, Peoria Interceptor and Havana Interceptor stations. In general, daily peaks in streamflow during baseflow conditions occurred after midnight each day, indicating that evening or nightly lawn watering in the residential areas south of the RMA may contribute to streamflow or evaporation is low at this time. Due to differences in the length of the storm sewer system and/or open channel storm drainages among South Uvalda, Peoria Interceptor and Havana Interceptor basins, direct comparisons of diurnal fluctuations cannot be made. Additionally, the Havana Interceptor basin is primarily commercial with very limited areas of vegetation, thus runoff can occur more quickly. Travel times in the concrete-lined Havana Interceptor are also much shorter than travel times in the natural open channel which conveys streamflow to the Uvalda Interceptor. Finally, the Peoria Interceptor drainage basin is composed of nearly 100 percent storm sewers which travel to the Peoria Interceptor via a 10-foot squash culvert under 56th Street on the south side of the Arsenal.

4.1.3.4 Streamflow Storm Runoff Hydrographs. Streamflow storm hydrographs observed at RMA during Water Year 1989 represent flow conditions in response to precipitation events typical for this area of Colorado. The summer and fall seasons produced storm hydrographs that are typical of short duration afternoon thunderstorms. Precipitation events during winter months were typically multi-day events with no major accumulations occurring in any one short-time period. Multi-day storms with high intensity peaks of short duration occurred in the spring.

Six high, or extended, precipitation storms (May 10, 1989; May 13-15, 1989; May 31, 1989; June 2-4, 1989; July 29, 1989; September 7-12, 1989), were analyzed to describe flow conditions in response to precipitation events (Table 4.1-6). These precipitation events generally lasted for one to eight hours, however, several long duration precipitation events exhibited a steady rainfall rate with short periods of high accumulations. The shorter precipitation events were brief thunderstorms with high rainfall accumulation.

Several of the stations responded in a similar manner to precipitation events and were separated into four groups. One group includes monitoring stations Havana Interceptor, Peoria Interceptor, South Uvalda, and Basin A. These stations responded in a manner typical of watersheds affected by urbanization. Response to precipitation occurred almost immediately after the beginning of rainfall at all of the stations. Peak flows occurred within three hours at all of these stations. In general, streamflow recession lasted from three to 30 hours after the storm event ended. Streamflow recession varied depending on the size of the drainage area and the soil moisture conditions at the time of the storm.

The second group, South First Creek and North First Creek, exhibited a similar response to precipitation. The response times to precipitation events on First Creek varied throughout the year depending on the baseflow conditions present at the time of the storm and the spatial distribution of rainfall. Snowmelt and/or associated high ground-water levels maintained higher baseflow conditions in First Creek into the summer months. During the spring and early summer months, when high ground-water conditions were influencing flow, response to precipitation occurred within one to two hours after rainfall began. In late summer and fall, response times were longer, approximately three to five hours, due to the drier ground conditions. In general, streamflow recession lasted approximately one day after the storm event ended.

The third group included Highline Lateral, Ladora Weir and North Uvalda. An analysis of response to precipitation is not meaningful as these are stations that receive flow from controlled releases.

The fourth and final group consisted of only one station, South Plants Ditch. For most of the year (when the antecedent soil moisture conditions are low (dry) on RMA), the station was dry and did not respond to precipitation. The only response to precipitation that occurred was during a large rainfall event on June 3 - 4, 1989, when the soil moisture conditions were higher.

4.1.3.5 South Plant Lakes and Havana Pond Trends and Extremes. South Plant Lakes and Havana Pond storage volumes have been calculated for Water Year 1989. The South Plants Lakes

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TABLE 4.1-6 COMPARISON OF HIGH AND EXTENDED PRECIPITATION EVENTS AND MEAN DAILY DISCHARGES

	MAY 10*	MAY 13	MAY 14*	MAY 15	MAY 31	JUNE 2	JUNE 3	JUNE 4	JULY 29	SEPT 7	SEPT 8	SEPT 9	SEPT 10	SEPT 11	SEPT 12
TOTAL DAILY PRECIPITATION (inches)	0.13	0.18	1.08	0.76	0.67	0.84	0.65	0.17	1.44	0.15	0.27	0.10	0.41	0.15	0.37
MEAN DAILY DISCHARGE (cfs)															
South Uvalda	1.30	3.30	10.00	4.30	6.90	4.00	9.60	2.90	20.00	5.50	2.80	1.10	2.80	1.90	3.50
Peoria Interceptor	1.10	1.50	6.00	2.60	8.40	1.30	9.10	18.60	8.70	0.22	5.50	2.90	4.00	3.70	6.20
Havana Interceptor	NR	NR	NR	NR	12.00	21.00	36.00	3.30	71.00	5.10	5.50	2.00	7.00	3.30	4.90
Basin A	T	T	0.09	0.08	0.05	T	0.12	0.11	0.02	T	T	T	T	0.01	0.01
South First Creek	1.40	1.40	2.60	4.70	1.50	1.40	2.50	2.70	0.54	0.00	0.01	0.07	0.13	0.26	0.48
North First Creek	1.30	0.69	1.30	3.30	0.88	1.70	3.60	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Uvalda	0.06	0.00	0.00	0.00	65.00	37.00	12.00	0.48	0.00	0.05	0.05	0.05	0.05	0.05	0.05
Ladora Weir	NR	NR	NR	NR	0.00	0.00	0.00	0.00	12.00	0.06	0.06	0.06	0.06	0.06	0.06
Highline Lateral	0.00	0.00	0.00	0.00	20.00	9.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* - Storm sample collected

T - Discharge >0.00 cfs, <0.005 cfs

NR - No record

and Havana Pond are all included in the Irondale Gulch drainage basin. Storage volumes for Lake Mary have not been established and cannot be presented because the lake area has never been surveyed. These volumes are based on area/stage relationships established by previous contractors (Ebasco Services, Inc., et al., 1989a). Previously established and surveyed stage/elevation information did not correspond to recently surveyed information that was compiled for CMP surface-water program. (Appendix A-1.1 contains the monitoring station survey information.) These differing stage/elevation relationships are detailed in Table 4.1-7.

Table 4.1-7 Stage/Elevation Survey Information

	Water RI, 1989		CMP 1989		Difference in Elevation (ft)
	Stage (ft)	Elevation (ft-msl)	Stage (ft)	Elevation (ft-msl)	
Havana Pond	0.00	5244.20	0.00	5244.08	0.12
Upper Derby Lake	0.00	5249.25	0.00	5247.77	1.48
Lower Derby Lake	0.00	5231.00	0.00	5230.17	0.83
Ladora Lake	0.00	5208.00	0.00	5207.11	0.89
Lake Mary	0.00	5202.63	0.00	5202.39	0.24

Net average volumes were calculated for each water body and were based on previously determined elevation/volume relationships (Appendix A-9). Average net volumes for each water body were determined for the months with sufficient data. The lakes and Havana Pond are typically frozen in December and January, thus, levels were not measured during these months. Estimated precipitation and evaporation volumes were calculated by multiplying the average monthly lake/pond area in areas by the precipitation or evaporation depth in feet to yield an acre-feet value. The average monthly volumes are net average volumes, as they reflect the monthly evaporation and precipitation volumes. Table 4.1-8 summarizes average storage volumes for the South Plants Lakes and Havana Pond.

4.1.3.5.1 Havana Pond. - Stage at Havana Pond was monitored continuously with a Stevens Type F recorder and weekly by observed staff gage readings. Havana Pond storage water originates from water derived from Peoria and Havana Interceptors. Average storage volumes for Havana Pond, which were based on the weekly observed staff gage readings, ranged from a low of 17.04 ac-ft in April to a high of 40.69 ac-ft in August (Figure 4.1-39 and Table 4.1-8). During October and November 1989 and February and March 1989 the pond water was below gage and/or

Table 4.1-8 Average Storage, Precipitation and Evaporation Volumes for South Plants Lakes and Havana Pond, Water Year 1989.

Month/Year	Average Storage Volume (ac-ft)	Precipitation (ac-ft)	Evaporation (ac-ft)
	Lower Derby Lake		
October	559.38	0.39	31.15
November	527.28	2.96	16.99
February	477.08	3.95	5.38
March	486.43	3.38	9.66
April	469.59	5.93	18.97
May	441.44	1.96	38.99
June	498.13	12.47	42.43
July	430.38	9.28	56.45
August	329.06	6.27	37.44
September	286.25	7.01	30.75
10 Month Average	450.51	7.36	28.82
	Ladora Lake		
October	298.63	0.27	21.91
November	304.94	2.18	12.51
February	315.83	3.14	4.28
March	311.07	2.63	7.52
April	307.26	4.66	15.04
May	302.65	17.65	31.34
June	300.36	9.35	31.81
July	274.95	7.05	42.90
August	301.52	5.88	35.10
September	261.57	6.42	28.17
10 Month Average	297.88	5.92	23.06

Table 4.1-8 Average Storage, Precipitation and Evaporation Volumes for South Plants Lakes and Havana Pond, Water Year 1989 (continued).

Month/Year	Average Storage Volume (ac-ft)	Precipitation (ac-ft)	Evaporation (ac-ft)
	Havana Pond		
April	17.04	0.97	3.09
May	37.17	5.71	0.15
June	36.15	3.01	10.26
July	24.74	1.98	12.04
August	40.69	2.02	12.08
September	32.08	2.13	9.35
6 Month Average	31.31	2.64	9.50
	Upper Derby Lake		
October	119.68	0.20	16.18
November	70.00	1.12	6.45
April	5.35	0.47	1.49
May	46.86	6.04	10.72
June	126.70	7.08	24.09
July	74.81	4.12	25.04
August	67.18	2.98	17.79
September	46.49	2.77	12.17
8 Month Average	69.63	3.10	14.24

frozen, and storage volumes could not be calculated. The average monthly net storage volume for the six-month time period was 31.31 ac-feet.

4.1.3.5.2 Upper Derby Lake. - Stage at Upper Derby Lake is monitored weekly by observed staff gage readings. Upper Derby Lake storage water originates from Uvalda Interceptor and/or Highline Lateral. Average storage volume for Upper Derby Lake ranged from a minimum of 1.30 ac-ft in April to a maximum of 126.70 ac-ft in June (Figure 4.1-40 and Table 4.1-8). The average storage volume for the six-month time period was 62.81 ac-feet.

4.1.3.5.3 Lower Derby Lake. - Stage at Lower Derby was monitored weekly by observed staff gage readings. Lower Derby Lake storage water originates from water derived from Upper Derby Lake, Uvalda Interceptor and/or Highline Lateral. Lower Derby Lake average monthly storage volume ranged from a low of 286.35 ac-ft in September to a high of 559.38 ac-ft in October (Figure 4.1-41 and Table 4.1-8). The average monthly net storage volume was 450.51 ac-feet, based on a 10 month record.

4.1.3.5.4 Ladora Lake. - Stage at Ladora Lake is monitored weekly from observed staff gage readings. Ladora Lake storage water is derived primarily from Lower Derby Lake and secondarily from Havana Pond. Average monthly net storage volumes ranged from a minimum of 261.57 ac-ft in September to a maximum of 315.83 ac-ft in February (Figure 4.1-42 and Table 4.1-8). The average monthly net storage volume was 297.88 ac-feet, based on a ten month record.

4.1.3.6 Sewage Treatment Plant Trends and Extremes. Water discharge from the Sewage Treatment Plant (STP) originates from treated water that is used on RMA. The water is discharged into a plastic-lined channel which leads to First Creek. The discharged water from the plant is monitored daily by Army personnel and observed weekly by Stollar personnel. Discharge records are provided in Appendix A-10.

A total of 5,271,400 gallons of water was discharged from the STP during Water Year 1989 (Table 4.1-9). The monthly discharge varied from a minimum of 118,400 gallons during April 1989 to a maximum of 862,400 gallons during August 1989. The average monthly discharge for Water Year 1989 was 439,283 gallons or 14,384 gallons/day. Weekly discharge measurements show a minimum weekly discharge of 13,100 gallons during the week of April 25, 1989 and a maximum weekly discharge of 218,900 gallons during the week of August 18, 1989 (Figure 4.1-43 and Appendix A-10).

Table 4.1-9 Sewage Treatment Plant Monthly Flow Summaries, Water Year 1989

Month	Monthly Total (gallons)	Daily Average (gpd)	Daily Average (gpm)
October 1988	438600	14148	9.83
November 1988	452000	15067	10.46
December 1988	400900	12932	8.98
January 1989	446800	14413	10.01
February 1989	264800	9457	6.57
March 1989	340000	10968	7.62
April 1989	118400	3947	2.74
May 1989	334000	10774	7.48
June 1989	377900	12597	8.75
July 1989	652100	21035	14.61
August 1989	862400	27819	19.32
September 1989	583500	19450	13.51
	439283	14384	9.99
TOTAL FOR YEAR	5271400		

4.1.3.7 South Uvalda Historical Stage Data Review Results. The South Uvalda (SW12005) gaging station records for the period October 1985 through September 1987 were selected for reanalysis. As discussed in Section 3.1.3, a preliminary analysis was conducted that led to a check of all strip charts: for starting and ending notations, baseline corrections, errors, recorder malfunctions, and channel obstructions. The results of this analysis are summarized for all 80 strip charts in Table 4.1-10 (Historical Strip Chart Reduction Preliminary Analysis). In general, the most apparent discrepancy was in the baseline notations, which often required corrections. A few strip charts were identified with missing starting and ending notations, recorder malfunctions, and/or channel obstructions. However, none of the errors or problems identified in the original historical strip chart review were significant enough to discredit the historical data.

Subsequently, the South Uvalda strip charts for October, 1985 through September, 1987, were digitized to allow comparison of stage and discharge between the digitized and historical (manually-reduced) records. This procedure is discussed in greater detail in Section 3.1.3.

The criteria for stage comparisons were based on a), whether the historical and digitized stage records compared to within $\pm$0.05 ft, b), whether stage records compared to within $\pm$0.10 ft, c), whether the time of the recorded peak matched within $\pm$1 hour, and d) whether the time of the recorded peak matched within $\pm$2 hours.

These criteria were chosen because the historical stage records were rounded to the nearest $\pm$0.05 ft, and it was desirable to make a check at that precision. The $\pm$0.10 ft criterion was set subjectively at twice the $\pm$0.05 ft increment. In addition, the historical records were reduced to show 24 hourly increments each day; the comparison is based on the hourly increment. A $\pm$2-hour comparison was subjectively chosen as twice the hourly increment, and also to reflect possible differences in records converted to standard time (all digital records) versus those reflecting daylight savings time periods (some historical records).

When stage records are converted to discharge records, the historical discharge values (instantaneously peak, daily means and total volumes) should be within 10 percent of the newly digitized discharge values to be considered acceptable. The 10 percent criterion was chosen because the previous $\pm$0.05-ft stage criterion was generally equivalent to a 10 percent change in discharge relevant to the historical rating relationship.

The difference between the magnitude and timing of 97 historically-reduced instantaneous peaks versus the newly digitized instantaneous peaks is summarized in Table 4.1-11 (Comparison of

Table 4.1-10 Historical Strip Chart Reduction Preliminary Analysis

Period Identification	Missing Start Time and Stage Notation		Missing End Time and Stage Notation		Baseline Correction Required		Errors		Recorder Malfunctions/ Missing Record		Channel Obstructions		Comments
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	
10/01/85 - 10/04/85		X		X	X			X		X		X	Chart started on wrong scale
10/07/85 - 10/14/85		X		X	X			X		X		X	Chart started on wrong scale
10/14/85 - 10/21/85		X	X		X			X		X		X	Chart started on wrong scale, date & time
10/21/85 - 10/28/85		X		X	X			X		X		X	Chart started on wrong scale
10/28/85 - 11/04/85		X		X	X			X		X		X	
11/04/85 - 11/11/85		X		X		X		X		X		X	
11/11/85 - 11/18/85		X		X	X			X		X		X	Chart started on wrong scale
11/18/85 - 11/25/85		X		X	X			X		X		X	Chart started on wrong scale
11/25/85 - 12/02/85		X	X		X			X		X		X	Chart started on wrong scale; missing end time
12/02/85 - 12/09/85		X		X	X			X		X		X	Chart started on wrong scale
12/09/85 - 12/16/85		X		X		X		X		X		X	
03/03/86 - 03/10/86		X		X		X		X		X		X	
03/10/86 - 03/17/86		X		X		X		X		X		X	
03/17/86 - 03/24/86		X		X	X			X		X		X	Chart started on wrong scale
03/24/86 - 03/31/86		X		X		X		X		X		X	
03/24/86 - 03/31/86		X		X		X		X		X		X	
03/31/86 - 04/07/86		X	X			X		X		X		X	Wrong end date & time
04/07/86 - 04/14/86		X		X		X		X		X		X	
04/14/86 - 04/21/86		X		X		X		X		X		X	
04/21/86 - 04/29/86		X		X		X	X			X		X	Trace off paper
04/29/86 - 05/05/86		X		X		X		X		X		X	
05/05/86 - 05/12/86		X		X		X		X		X		X	
05/12/86 - 05/19/86		X		X		X		X		X	X		Rocks in V-Notch
05/19/86 - 05/26/86		X	X			X		X		X		X	Wrong ending time
05/26/86 - 05/02/86		X		X		X		X		X		X	
06/02/86 - 06/09/86		X		X		X		X		X		X	
06/09/86 - 06/16/86		X		X		X		X		X		X	
06/16/86 - 06/23/86		X		X		X		X		X		X	
06/23/86 - 06/30/86		X		X		X		X		X		X	

Table 4.1-10 Historical Strip Chart Reduction Preliminary Analysis (continued)

Period Identification	Missing Start Time and Stage Notation		Missing End Time and Stage Notation		Baseline Correction Required		Errors		Recorder Malfunctions/ Missing Record		Channel Obstructions		Comments
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	
06/30/86 - 07/07/86		X		X		X		X		X		X	
07/07/86 - 07/14/86		X		X		X		X		X		X	
07/07/86 - 07/14/86		X		X		X		X		X		X	
07/14/86 - 07/21/86		X	X			X		X		X		X	End date & time missing
07/21/86 - 07/28/86		X		X		X		X		X		X	
07/28/86 - 08/04/86		X		X		X		X		X		X	
08/04/86 - 08/11/86		X		X		X		X	X			X	Intake pipes clogged
08/11/86 - 08/18/86		X		X		X		X		X		X	
08/18/86 - 08/25/86		X		X		X		X		X	X		Trash dam
08/25/86 - 09/01/86		X		X		X		X		X		X	
09/01/86 - 09/08/86		X		X		X		X		X		X	
09/08/86 - 09/15/86		X		X		X		X		X		X	
09/15/86 - 09/22/86		X		X		X		X		X		X	
09/22/86 - 09/29/86		X		X	X			X		X		X	Chart started on wrong scale
09/29/86 - 10/06/86		X		X		X		X	X		X		Notch obstructed
10/06/86 - 10/13/86	X			X	X			X		X	X		Wrong starting notation/Notch obstructed
10/13/86 - 10/20/86		X		X		X		X		X	X		Notch obstructed
10/20/86 - 10/27/86	X		X		X			X		X	X		Wrong starting & end notation /Notch cleared
10/27/86 - 11/03/86		X		X		X		X		X	X		Notch obstructed
11/03/86 - 11/10/86	X			X		X		X		X	X		Wrong starting notation /Notch cleared
11/10/86 - 11/17/86		X		X		X		X		X		X	
11/17/86 - 11/24/86		X		X		X		X		X		X	
11/24/86 - 12/01/86		X	X			X		X		X		X	Wrong ending stage notation
12/01/86 - 12/08/86	X			X	X			X		X		X	Wrong starting notation
03/31/87 - 04/06/87		X		X		X		X		X		X	
04/06/87 - 04/13/87		X		X		X		X		X		X	
04/13/87 - 04/20/87		X		X	X			X		X		X	Chart started on wrong scale
04/20/87 - 04/27/87		X		X		X		X		X		X	
04/27/87 - 05/04/87		X		X		X		X	X			X	Clock stopped

Table 4.1-10 Historical Strip Chart Reduction Preliminary Analysis (continued)

Period Identification	Missing Start Time and Stage Notation		Missing End Time and Stage Notation		Baseline Correction Required		Errors		Recorder Malfunctions/ Missing Record		Channel Obstructions		Comments
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	
05/04/87 - 05/11/87		X		X		X		X	X			X	Clock stopped/Battery replaced
05/11/87 - 05/18/87		X		X		X		X		X		X	
05/18/87 - 05/26/87		X		X		X		X	X			X	Float cable off pully
05/26/87 - 06/01/87		X		X		X		X		X		X	
06/01/87 - 06/08/87		X		X		X		X		X		X	
06/08/87 - 06/15/87		X		X		X		X	X			X	Float cable off pully
06/22/87 - 06/29/87		X		X		X		X		X		X	
06/29/87 - 07/06/87		X		X	X			X		X		X	
07/06/87 - 07/13/87		X		X		X		X		X		X	Chart started at wrong scale
07/13/87 - 07/20/87		X		X		X		X		X		X	
07/20/87 - 07/27/87		X		X		X		X		X		X	
07/27/87 - 08/03/87		X		X		X		X		X		X	
08/03/87 - 08/10/87		X		X		X		X		X		X	
08/03/87 - 08/10/87		X		X		X		X		X		X	
08/10/87 - 08/17/87		X		X		X		X		X		X	
08/17/87 - 08/24/87		X		X		X		X	X			X	Float cable off pully
08/24/87 - 08/31/87		X		X		X		X		X		X	
08/31/87 - 09/07/87		X		X		X		X	X			X	Float cable off pully
09/07/87 - 09/14/87		X		X		X		X		X		X	
09/14/87 - 09/21/87		X		X		X		X	X			X	Float cable off pully
09/21/87 - 09/28/87		X		X		X		X		X		X	
09/28/87 - 10/05/87		X		X		X		X		X		X	

Table 4.1-11 Comparison of Instantaneous Peak Stages

	Historical Record		Digitized Record				
Date	Time (hrs)	Peak Stage (ft)	Time (hrs)	Peak Stage (ft)	Time Difference (hrs)	Peak Stage Difference* (ft)	Comments
10/01/85	14.00	4.20	14.23	4.18	0.23	-0.02	
10/11/85	5.00	4.60	4.78	4.77	-0.22	0.17	
10/11/85	10.00	4.20	10.38	4.30	0.38	0.10	
10/13/85	13.00	4.25	12.80	4.28	-0.20	0.03	
10/13/85	21.00	4.65	21.69	4.68	0.69	0.03	
10/14/85	12.00	4.10	12.44	4.15	0.44	0.05	
10/31/85	17.00	5.00	17.70	5.06	0.70	0.06	
10/31/85	19.00	4.80	19.50	4.86	0.50	0.06	
11/09/85	9.00	4.65	9.57	4.73	0.57	0.08	
11/09/85	15.00	4.20	15.83	4.21	0.83	0.01	
11/10/85	14.00	4.10	13.90	4.13	-0.10	0.03	
11/11/85	14.00	4.25	13.92	4.27	-0.08	0.02	
11/15/85	12.00	4.70	12.06	4.73	0.06	0.03	
11/19/85	14.00	4.15	13.67	4.17	-0.33	0.02	
11/20/85	14.00	4.15	13.71	4.19	-0.29	0.04	
11/25/85	13.00	4.30	13.92	4.31	0.92	0.01	
12/15/85	16.00	4.05	16.41	4.08	0.41	0.03	
03/17/86	0.00	4.20	0.55	4.38	0.55	0.18	
03/17/86	12.00	4.75	12.19	4.82	0.19	0.07	
03/19/86	18.00	4.25	18.28	4.30	0.28	0.05	
03/20/86	10.00	4.25	23.84	4.21	-10.16	-0.04	Digitized Peak on 03/19/86
03/20/86	9.00	4.30	8.76	4.28	-0.24	-0.02	
04/02/86	19.00	5.50	19.60	5.87	0.60	0.37	
04/04/86	15.00	5.70	16.58	5.81	1.58	0.11	
04/05/86	11.00	5.15	12.08	5.19	1.08	0.04	
04/06/86	14.00	4.85	14.37	4.84	0.37	-0.01	

* Magnitude Difference = Digitized Peak Magnitude - Historical Peak Magnitude

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Table 4.1-11 Comparison of Instantaneous Peak Stages (continued)

Date	Historical Record		Digitized Record		Time Difference (hrs)	Peak Stage Difference* (ft)	Comments
	Time (hrs)	Peak Stage (ft)	Time (hrs)	Peak Stage (ft)			
04/07/86	15.00	4.65	14.54	4.67	-0.46	0.02	
04/09/86	8.00	4.60	7.30	4.61	-0.70	0.01	
04/11/86	21.00	4.65	20.34	4.88	-0.66	0.23	
04/17/86	12.00	5.10	12.94	5.16	0.94	0.06	
04/20/86	24.00	4.90	1.33	4.92	1.33	0.02	Digitized peak on 04/21/86
04/26/86	12.00	4.40	16.69	4.67	4.69	0.27	
05/08/86	3.00	4.30	2.16	4.45	-0.84	0.15	
05/08/86	15.00	4.85	15.96	4.88	0.96	0.03	
05/15/86	14.00	4.85	14.15	5.17	0.15	0.32	
05/16/86	3.00	4.95	3.94	5.05	0.94	0.10	
06/02/86	1.00	4.60	1.37	4.74	0.37	0.14	
06/02/86	7.00	4.35	7.57	4.31	0.57	-0.04	
06/08/86	18.00	4.60	18.84	4.72	0.84	0.12	
06/09/86	10.00	4.25	10.73	4.28	0.73	0.03	
06/10/86	7.00	5.15	8.08	5.20	1.08	0.05	
06/16/86	21.00	4.40	22.05	4.67	1.05	0.27	
07/05/86	20.00	4.70	20.01	4.83	0.01	0.13	
07/16/86	18.00	4.50	19.27	4.36	1.27	-0.14	
07/17/86	20.00	5.85	21.10	6.38	1.10	0.53	
07/20/86	20.00	4.95	20.76	5.01	0.76	0.06	
07/22/86	20.00	4.45	20.45	4.49	0.45	0.04	
08/02/86	20.00	6.25	21.35	6.60	1.35	0.35	
08/16/86	22.00	4.15	22.45	4.17	0.45	0.02	
08/22/86	21.00	4.80	21.71	4.83	0.71	0.03	

* Magnitude Difference = Digitized Peak Magnitude - Historical Peak Magnitude

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Table 4.1-11 Comparison of Instantaneous Peak Stages (continued)

Date	Historical Record Time (hrs)	Historical Record Peak Stage (ft)	Digitized Record Time (hrs)	Digitized Record Peak Stage (ft)	Time Difference (hrs)	Peak Stage Difference* (ft)	Comments
08/29/86	18.00	4.40	18.81	4.41	0.81	0.01	
09/07/86	24.00	4.35	23.83	4.39	-0.17	0.04	
09/24/86	14.00	4.10	14.42	4.13	0.42	0.03	
10/03/86	6.00	4.20	6.94	4.20	0.94	0.00	
10/03/86	23.00	4.35	23.93	4.34	0.93	-0.01	
10/09/86	1.00	4.35	1.92	4.35	0.92	0.00	
10/10/86	21.00	5.15	22.10	5.17	1.10	0.02	
10/11/86	4.00	4.40	5.07	4.40	1.07	0.00	
10/23/86	1.00	4.10	0.00	4.34	-1.00	0.24	
10/23/86	17.00	4.75	16.53	4.81	-0.47	0.06	
10/31/86	9.00	4.35	9.43	4.34	0.43	-0.01	
10/31/86	20.00	4.50	21.42	4.51	1.42	0.01	
11/01/86	3.00	4.45	3.65	4.44	0.65	-0.01	
11/07/86	3.00	4.75	3.33	4.72	0.33	-0.03	
11/30/86	17.00	4.05	17.90	4.08	0.90	0.03	
12/01/86	14.00	4.55	13.82	4.56	-0.18	0.01	
12/07/86	15.00	4.20	15.33	4.21	0.33	0.01	
04/01/87	21.00	4.25	22.66	4.22	1.66	-0.03	
04/02/87	10.00	4.25	11.35	4.21	1.35	-0.04	
04/12/87	12.00	4.70	12.86	4.79	0.86	0.09	
04/13/87	15.00	4.15	15.19	4.16	0.19	0.01	
04/20/87	7.00	4.55	7.79	4.48	0.79	-0.07	
05/01/87	17.00	4.80	15.90	5.16	-1.10	0.36	
05/02/87	18.00	4.60	17.07	4.72	-0.93	0.12	

* Magnitude Difference = Digitized Peak Magnitude - Historical Peak Magnitude

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Table 4.1-11 Comparison of Instantaneous Peak Stages (continued)

Date	Historical Record		Digitized Record		Time Difference (hrs)	Peak Stage Difference* (ft)	Comments
	Time (hrs)	Peak Stage (ft)	Time (hrs)	Peak Stage (ft)			
05/02/87	22.00	5.05	22.04	5.16	0.04	0.11	
05/12/87	20.00	4.20	19.41	4.22	-0.59	0.02	
05/17/87	19.00	4.10	18.51	4.11	-0.49	0.01	
05/20/87	9.00	4.30	8.47	4.24	-0.53	-0.06	
05/20/87	23.00	4.85	21.81	4.43	-1.19	-0.42	
05/21/87	19.00	5.35	18.21	4.73	-0.79	-0.62	
05/30/87	21.00	4.45	21.46	4.05	0.46	-0.40	
06/09/87	1.00	5.75	0.00	3.92	-1.00	-1.83	
06/09/87	18.00	4.70	18.88	4.25	0.88	-0.45	
06/18/87	21.00	5.10	20.59	4.21	-0.41	0.89	
06/19/87	3.00	4.15	3.22	4.15	0.22	0.00	
06/28/87	20.00	4.20	19.21	4.14	-0.79	-0.06	
06/29/87	1.00	5.40	0.01	5.24	-0.99	-0.16	
06/29/87	18.00	7.70	18.90	4.84	0.90	-2.86	
07/12/87	9.00	4.75	8.52	4.80	-0.48	0.05	
07/24/87	1.00	5.40	0.00	5.24	-1.00	-0.16	
07/29/87	18.00	4.30	18.92	4.35	0.92	0.05	
07/31/87	18.00	4.15	18.16	4.00	0.16	-0.15	
07/21/87	27.00	4.05	21.01	4.11	-5.99	0.06	
07/24/87	1.00	5.40	23.64	5.84	-1.36	0.44	Digitized peak on 07/23/87
07/25/87	22.00	4.05	19.61	4.35	-2.39	0.30	
07/26/87	22.00	4.05	21.33	4.21	-0.67	0.16	
09/14/87	24.00	5.05	21.75	5.90	-2.25	0.85	

* Magnitude Difference = Digitized Peak Magnitude - Historical Peak Magnitude.

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Instantaneous Peak Stages). In general, the time difference between the digitized record and the historical record was less than one hour. About 80 percent of the historical records showed timing of peak flows within two hours of the digitized records. The difference in peak stage was ±0.05 ft or less for 53 percent of the peaks. However, only 66 percent of the peaks differed by ±0.10 ft or less, and differences ranged to as much as 2.86 ft. This showed that significant errors occurred in the historical reduction of stage data, and that rounding the time of the peak to the nearest hour created a timing error for 20 percent of the values.

Ten randomly-selected points from each month (except for periods of no record), showing the historical stage value along with the corresponding digitized stage value are listed in Table 4.1-12 (General Stage Comparison). For this analysis, the historical stage value was within ±0.05 ft of the newly digitized stage value for 83 percent of the values, and within ±0.10 ft for 92 percent of the values. This analysis included a high proportion of baseflow conditions, for which the historical and digitized values should be very close; this accounts for the relatively high agreement between these data sets.

The final step in the review included a comparison of the historical discharge records to newly computed discharge records based on digitized strip charts. This step included:

- comparison of the monthly instantaneous minimum and maximum stages and flows,
- comparison of the minimum and maximum daily mean flows, and
- comparison of the total monthly flows.

The differences between the instantaneous minimum and maximum stages and flows for each month of record are summarized in Table 4.1-13 (Comparison of the Monthly Instantaneous Minimum and Maximum Stages and Flows). Approximately 84 percent of the instantaneous minimum stages were within ±0.05 ft of each other, and about 62 percent of the instantaneous maximum stages were within ±0.05 ft of each other. About 42 percent of the historical minimum discharge values were within 10 percent of the digitized minimum discharge values. About 95 percent of the historical maximum discharge values differed by more than 10 percent from the digitized maximum discharge values, and the difference ranged up to 214 percent. Again, this shows greater agreement between values during low flows, and divergence between values at higher flows. Significant departures occurred in historical reductions for monthly instantaneous maximum stage. Values for both minimum and maximum instantaneous discharges contained significant errors when compared to digitized discharges.

Table 4.1-12 General Stage Comparison

Date	Time (hrs)	Historical Stage (ft)	Digitized Stage (ft)	Difference* (ft)
10/02/85	2.00	4.00	3.97	-0.03
10/05/85	20.00	3.95	3.95	0.00
10/07/85	8.00	3.95	3.95	0.00
10/09/85	5.00	3.90	3.94	0.04
10/12/85	3.00	3.90	3.92	0.02
10/14/85	17.00	3.95	3.94	-0.01
10/19/85	23.00	3.90	3.93	0.03
10/24/85	20.00	3.95	3.93	-0.02
10/27/85	12.00	3.90	3.92	0.02
10/30/85	6.00	3.95	3.92	-0.03
11/01/85	10.00	3.95	3.94	-0.01
11/03/85	7.00	3.95	3.95	0.00
11/06/85	20.00	3.95	3.97	0.02
11/09/85	14.00	4.10	4.08	-0.02
11/13/85	15.00	4.00	4.01	0.01
11/16/85	22.00	3.95	3.93	-0.02
11/19/85	19.00	3.95	3.96	0.01
11/23/85	9.00	3.90	3.91	0.01
11/25/85	7.00	3.95	3.91	-0.04
11/29/85	4.00	3.90	3.94	0.04
12/01/85	13.00	3.90	3.94	0.04
12/04/85	14.00	3.95	3.95	0.00
12/07/85	19.00	3.95	3.92	-0.03
12/11/85	4.00	3.90	3.90	0.00
12/15/85	19.00	4.00	4.01	0.01
03/05/86	23.00	3.90	3.90	0.00
03/09/86	5.00	3.90	3.90	0.00
03/11/86	18.00	3.90	3.91	0.01
03/16/86	8.00	3.90	3.89	-0.01
03/17/86	12.00	4.75	4.44	-0.31
03/20/86	3.00	4.10	4.01	-0.09
03/21/86	2.00	3.90	3.88	-0.02
03/24/86	8.00	3.90	3.89	-0.01
03/28/86	16.00	3.95	3.98	0.03
03/31/86	5.00	3.90	3.91	0.01
04/01/86	17.00	3.90	3.90	0.00
04/03/86	18.00	3.90	3.88	-0.02
04/05/86	14.00	4.95	4.94	-0.01
04/08/86	12.00	4.35	4.30	-0.05
04/10/86	20.00	4.00	4.01	0.01
04/14/86	18.00	4.00	4.00	0.00
04/18/86	1.00	4.00	4.01	0.01
04/21/86	20.00	4.00	3.98	-0.02
04/25/86	1.00	4.00	3.99	-0.01
04/30/86	23.00	4.00	4.00	0.00
05/02/86	2.00	4.05	3.99	-0.06
05/05/86	11.00	4.00	4.02	0.02
05/08/86	19.00	4.15	4.14	-0.01

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Table 4.1-12 General Stage Comparison (continued)

Date	Time (hrs)	Historical Stage (ft)	Digitized Stage (ft)	Difference* (ft)
05/11/86	7.00	3.95	3.97	0.02
05/13/86	22.00	4.05	4.05	0.00
05/16/86	2.00	4.80	4.91	0.11
05/19/86	21.00	4.00	3.97	-0.03
05/22/86	2.00	3.95	4.03	0.08
05/26/86	4.00	4.00	4.07	0.07
05/28/86	15.00	4.00	4.02	0.02
06/04/86	5.00	3.95	3.99	0.04
06/07/86	8.00	3.95	3.95	0.00
06/10/86	10.00	4.55	4.80	0.25
06/11/86	22.00	4.00	3.99	-0.01
06/15/86	14.00	4.00	4.04	0.04
06/18/86	5.00	4.00	4.00	0.00
06/22/86	20.00	4.05	4.06	0.01
06/25/86	19.00	4.05	4.04	-0.01
06/27/86	12.00	4.00	4.01	0.01
06/30/86	9.00	4.00	3.98	-0.02
07/01/86	15.00	4.00	3.99	-0.01
07/05/86	21.00	4.45	4.59	0.14
07/09/86	5.00	3.95	3.97	0.02
07/11/86	23.00	4.05	4.04	-0.01
07/12/86	2.00	3.95	3.99	0.04
07/16/86	14.00	4.00	4.01	0.01
07/18/86	15.00	4.00	4.00	0.00
07/22/86	2.00	4.00	4.01	0.01
07/25/86	6.00	4.00	4.00	0.00
07/30/86	3.00	4.05	4.03	-0.02
08/02/86	20.00	6.25	4.17	-2.08
08/05/86	23.00	4.00	4.02	0.02
08/11/86	18.00	4.00	4.01	0.01
08/13/86	1.00	4.10	4.07	-0.03
08/16/86	15.00	3.95	3.97	0.02
08/19/86	18.00	4.00	3.98	-0.02
08/23/86	1.00	4.05	4.06	0.01
08/25/86	12.00	3.95	3.98	0.03
08/30/86	2.00	3.95	3.99	0.04
08/31/86	7.00	3.95	3.95	0.00
09/01/86	8.00	3.95	3.95	0.00
09/02/86	15.00	3.95	3.95	0.00
09/05/86	7.00	4.00	3.99	-0.01
09/09/86	22.00	3.95	3.93	-0.02
09/15/86	4.00	4.00	3.99	-0.01
09/16/86	13.00	3.95	3.92	-0.03
09/19/86	7.00	4.00	3.97	-0.03
09/24/86	14.00	4.10	4.11	0.01
09/25/86	12.00	3.95	3.96	0.01
09/29/86	4.00	4.00	4.07	0.07

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Table 4.1-12 General Stage Comparison (continued)

Date	Time (hrs)	Historical Stage (ft)	Digitized Stage (ft)	Difference* (ft)
10/01/86	6.00	4.05	4.06	0.01
10/02/86	19.00	4.00	3.98	-0.02
10/08/86	21.00	3.95	3.95	0.00
10/10/86	12.00	3.95	3.94	-0.01
10/11/86	6.00	4.20	4.33	0.13
10/21/86	15.00	3.95	3.94	-0.01
10/23/86	2.00	4.00	4.03	0.03
10/24/86	3.00	3.95	3.95	0.00
10/29/86	8.00	3.95	3.94	-0.01
10/31/86	22.00	4.35	4.43	0.08
11/01/86	1.00	4.30	4.34	0.04
11/02/86	14.00	4.00	3.98	-0.02
11/03/86	17.00	3.95	3.92	-0.03
11/07/86	18.00	3.95	3.93	-0.02
11/12/86	4.00	3.90	3.89	-0.01
11/16/86	11.00	3.90	3.89	-0.01
11/17/86	3.00	3.85	3.88	0.03
11/19/86	7.00	3.85	3.88	0.03
11/23/86	20.00	3.85	3.88	0.03
11/30/86	9.00	3.90	3.90	0.00
12/01/86	11.00	3.90	3.92	0.02
12/02/86	21.00	3.90	4.02	0.12
12/05/86	17.00	3.95	3.93	-0.02
12/07/86	14.00	4.15	4.13	-0.02
04/02/87	1.00	4.05	4.05	0.00
04/02/87	3.00	3.95	4.00	0.05
04/04/87	15.00	3.90	3.87	-0.03
04/11/87	15.00	3.90	3.96	0.06
04/18/87	2.00	3.95	4.10	0.15
04/20/87	8.00	4.30	4.48	0.18
04/21/87	20.00	3.90	3.90	0.00
04/23/87	12.00	3.90	3.90	0.00
04/27/87	15.00	3.90	3.88	-0.02
04/29/87	17.00	3.95	3.94	-0.01
05/01/87	13.00	3.95	3.97	0.02
05/02/87	20.00	4.50	4.52	0.02
05/03/87	9.00	4.00	3.98	-0.02
05/09/87	13.00	3.90	3.90	0.00
05/16/87	9.00	3.95	3.95	0.00
05/18/87	3.00	3.95	3.99	0.04
05/20/87	11.00	4.20	4.10	-0.10
05/21/87	18.00	5.00	4.73	-0.27
05/26/87	11.00	3.90	3.92	0.02
05/31/87	9.00	4.00	3.97	-0.03
06/06/87	6.00	3.80	3.90	0.10
06/08/87	7.00	3.95	3.95	0.00
06/10/87	12.00	3.95	3.94	-0.01

Table 4.1-12 General Stage Comparison (continued)

Date	Time (hrs)	Historical Stage (ft)	Digitized Stage (ft)	Difference* (ft)
06/12/87	9.00	3.95	3.98	0.03
06/14/87	13.00	3.90	3.96	0.06
06/18/87	19.00	4.35	4.20	-0.15
06/25/87	13.00	3.95	3.94	-0.01
06/29/87	1.00	5.40	4.95	-0.45
06/29/87	8.00	4.15	4.04	-0.11
06/30/87	16.00	3.90	3.95	0.05
07/02/87	16.00	3.90	3.94	0.04
07/04/87	22.00	3.90	3.98	0.08
07/08/87	4.00	3.90	4.05	0.15
07/09/87	22.00	4.00	4.08	0.08
07/10/87	15.00	4.00	4.03	0.03
07/14/87	10.00	3.95	3.96	0.01
07/15/87	3.00	4.00	4.00	0.00
07/17/87	9.00	3.95	3.99	0.04
07/20/87	18.00	3.95	3.99	0.04
07/23/87	19.00	4.00	4.04	0.04
08/05/87	16.00	4.05	4.00	-0.05
08/06/87	21.00	4.00	4.02	0.02
08/08/87	4.00	4.00	4.09	0.09
08/12/87	14.00	4.10	4.04	-0.06
08/16/87	8.00	4.00	3.99	-0.01
08/21/87	20.00	4.00	4.09	0.09
08/25/87	20.00	4.20	4.34	0.14
08/26/87	4.00	4.20	4.16	-0.04
08/27/87	7.00	4.05	4.04	-0.01
08/31/87	23.00	4.00	4.00	0.00
09/04/87	1.00	4.00	4.02	0.02
09/08/87	16.00	4.00	4.00	0.00
09/10/87	13.00	4.00	4.01	0.01
09/10/87	16.00	4.00	4.00	0.00
09/12/87	9.00	4.00	4.02	0.02
09/14/87	7.00	4.05	4.04	-0.01
09/22/87	10.00	4.00	4.01	0.01
09/23/87	16.00	4.00	4.00	0.00
09/25/87	11.00	4.00	4.01	0.01
09/29/87	6.00	4.00	4.02	0.02

* Difference = Digitized Stage - Historical Stage.

Table 4.1-13 Comparison of the Monthly Instantaneous Minimum and Maximum Stages and Flows

	Historical Record				Digitized Record				Differences in Historical vs Digitized Record			
	Stage (ft)		Discharge (cfs)		Stage (ft)		Discharge (cfs)		Difference in stage (ft)		% Difference in discharge (cfs)	
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Oct 85	3.90	5.08	0.40	42.0	3.90	5.06	0.37	22.74	0.00	-0.02	-8.11	-84.70
Nov 85	3.89	4.78	0.40	8.4	3.90	4.73	0.37	5.48	0.01	-0.05	-8.11	-53.28
Dec 85	3.89	4.08	0.40	1.2	3.89	4.08	0.35	0.99	0.00	0.00	-14.29	-21.21
Mar 86	3.90	4.82	0.40	8.4	3.88	4.82	0.34	6.11	-0.02	0.00	-17.65	-37.48
Apr 86	3.76	5.86	0.20	121.0	3.76	5.87	0.16	48.54	0.00	0.01	-25.00	-149.28
May 86	3.91	5.22	0.40	52.0	3.94	5.17	0.47	27.16	0.03	-0.05	14.89	-91.46
Jun 86	3.94	4.78	0.50	8.4	3.93	5.20	0.44	27.89	-0.01	0.42	-13.64	69.88
Jul 86	3.88	6.42	0.40	181.0	3.93	6.38	0.44	71.04	0.05	-0.04	9.09	-154.79
Aug 86	3.90	6.62	0.40	202.0	3.92	6.60	0.42	82.95	0.02	-0.02	4.76	-143.52
Sep 86	3.91	4.37	0.40	2.8	3.90	4.39	0.37	3.56	-0.01	0.02	-8.11	21.35
Oct 86	3.90	5.22	0.40	52.0	3.88	5.17	0.34	27.16	-0.02	-0.05	-17.65	-91.46
Nov 86	3.85	4.75	0.30	7.6	3.86	4.72	0.30	5.41	0.01	-0.03	0.00	-40.48
Dec 86	3.87	4.56	0.30	4.7	3.86	4.56	0.30	4.44	-0.01	0.00	0.00	-5.86
Apr 87	0.00	4.72	0.00	6.8	3.84	4.79	0.27	5.89	3.84	0.07	100.00	-15.45
May 87	3.88	5.35	0.40	67.0	3.86	5.16	0.30	26.92	-0.02	-0.19	-33.33	-148.89
Jun 87	3.85	5.90	0.30	128.0	3.85	5.65	0.28	40.76	0.00	-0.25	-7.14	-214.03
Jul 87	3.85	5.81	0.30	118.0	3.92	5.84	0.42	47.42	0.07	0.03	28.57	-148.84
Aug 87	3.00	5.00	0.00	31.0	3.97	5.69	0.55	42.10	0.97	0.69	100.00	26.37
Sep 87	3.80	5.75	0.20	110.0	3.99	5.90	0.61	49.65	0.19	0.15	67.21	-121.55

* Stage difference = Digitized Record - Historic Record
** Discharge difference = ((Digitized Record - Historic Record)/Digitized Record) X 100

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Differences between the historical and digitized values of minimum and maximum daily mean flows for each month of record are summarized in Table 4.1-14 (Comparison of the Minimum and Maximum Daily Mean Flows). This comparison also revealed substantial differences between the historical and newly digitized record. For the minimum daily mean flows, the historical values differed by more than 10 percent from digitized values approximately 31 percent of the time. For the maximum daily mean flows, approximately 79 percent of the time the historical values differed from digitized values by more than 10 percent. Historical maximums were as much as 217 percent higher than digitized values. This shows that for both minimum and maximum daily mean flows, the historically-reduced values departed significantly from the more precise digitized values.

Comparison of total monthly flow volumes (Table 4.1-15) demonstrates that in general, the historical total monthly flows are higher than the digitized values. The historical total monthly flow differed by more than 10 percent from the digitized total monthly flow on about 68 percent of the values. The historical flow value exceeded the digitized flow value by a maximum percent difference of 119 percent. Again, this shows that historical stage data reduction created inaccuracies in discharge data.

When both low flow and peak flow records were included, the stage record was relatively close throughout the period of record. This is due to the high proportion of low flow values, which logically should be in close agreement. However, based on the stage comparisons, it is evident that the instantaneous peak stages were frequently in error in the historical record. The historical discharge record was consistently higher than the digitized discharge record. This was mainly due to the differences between the stage records and between the historical rating curve and the newly revised rating curve used to produce the new discharge records. The differences are greater at the higher stage values. In summary, the historical strip charts for South Uvalda were not accurately reduced, nor were the resulting stage records accurately converted to discharge records. Since the methods used to reduce South Uvalda gaging records historically were similar for all other stations, the credibility of historically-reduced strip charts, stage and discharge records for all RMA continuous-recording gaging stations is in question.

Table 4.1-14 Comparison of the Minimum and Maximum Daily Mean Flows

Month	Historic Discharge Record Min	Historic Discharge Record Max	Digitized Discharge Record Min	Digitized Discharge Record Max	% Difference Historical vs Digitized Discharge Record Min	% Difference Historical vs Digitized Discharge Record Max
Oct 85	0.40	2.8	0.39	2.0	-2.56%	-40.00%
Nov 85	0.40	1.5	0.38	1.5	-5.26%	0.00%
Dec 85	0.40	0.6	0.37	0.52	-8.11%	-15.38%
Mar 86	0.40	1.3	0.36	1.2	-11.11%	-8.33%
Apr 86	0.40	25.8	0.361	3.0	-11.11%	-98.46%
May 86	0.60	5.3	0.56	4.8	-7.14%	-10.42%
Jun 86	0.60	6.0	0.58	3.6	-3.45%	-66.67%
Jul 86	0.50	8.3	0.47	4.0	-6.38%	-107.50%
Aug 86	0.50	14.9	0.53	7.6	5.66%	-96.05%
Sep 86	0.40	0.8	0.42	0.8	4.76%	0.00%
Oct 86	0.40	3.5	0.39	2.4	-2.56%	-45.83%
Nov 86	0.30	1.6	0.31	1.9	3.23%	15.79%
Dec 86	0.30	1.1	0.31	1.1	3.23%	0.00%
Apr 87	0.30	2.5	0.32	2.8	6.25%	10.71%
May 87	0.40	11.1	0.33	3.5	-21.21%	-217.14%
Jun 87	0.20	9.4	0.30	4.7	33.33%	-100.00%
Jul 87	0.40	4.5	0.49	2.5	18.37%	-80.00%
Aug 87	0.60	38.3	0.63	22.0	4.76%	-74.09%
Sep 87	0.30	5.7	0.66	4.9	54.55%	-16.33%

* % Difference = ((Digitized Total - Historic Total)/Digitized Total) X 100

Table 4.1-15 Comparison of Total Monthly Flows

Month	Historical Total Monthly Flow (ac-ft)	Digitized Total Monthly Flow (ac-ft)	Percent Difference*
Oct 85	37.40	34.83	-7.38%
Nov 85	34.20	31.93	-7.11%
Dec 85**	14.90	13.60	-9.56%
Mar 86**	28.20	25.18	-11.99%
Apr 86	147.20	103.66	-42.00%
May 86	56.80	65.59	13.40%
Jun 86	58.30	48.46	-20.31%
Jul 86	73.30	57.86	-26.69%
Aug 86	75.40	64.72	-16.50%
Sep 86	34.80	32.51	-7.04%
Oct 86	49.00	44.11	-11.09%
Nov 86	27.10	26.14	-3.67%
Dec 86**	7.70	9.20	16.30%
Apr 87	33.90	9.05	13.19%
May 8	94.80	48.93	-93.75%
Jun 87	90.30	41.24	-118.96%
Jul 87	48.90	49.88	1.96%
Aug 87	134.40	91.24	-47.30%
Sep 87	61.80	54.92	-12.53%

* % Difference = ((Digitized Total - Historic Total)/Digitized Total) X 100

** Based on partial records for the month.

4.2 Surface-Water Quality Results

This section presents the results of the CMP FY89 surface-water quality monitoring program. Results have been segregated into the following major categories: (1) target organic compounds, (2) nontarget organic compounds, (3) trace inorganic constituents, (4) field parameters and (5) major inorganic constituents. An evaluation of quality control samples, including blanks, duplicates and confirmatory analyses is provided in Section 4.5.

4.2.1 Surface-Water Quality Program Overview

The CMP Surface-Water Technical Plan (Stollar, 1989) describes a program for analysis of a target list of organic and inorganic chemical species. This list includes organic compounds, major inorganic constituents, trace inorganic constituents and field parameters. Gas chromatography/mass spectrometry (GC/MS) analyses were performed on samples of surface-water inflows to the south and southeast boundaries of RMA and on a sample of the outflow of First Creek. All other surface-water samples were randomly selected for confirmatory analyses. The purpose of the GC/MS program was to confirm results for analytes detected by GC methods and to characterize further the quality of surface-water at RMA by identifying the presence of nontarget compounds. Analytical results reported include those listed in Appendix B. Analytical results are included for 26 samples that were collected in the spring, seven that were obtained during storm events and 12 that were collected in the fall.

Separate discussions are presented for (1) target organic compounds, (2) nontarget organic compounds, (3) trace inorganic constituents, (4) field parameters, (5) major inorganic constituents and (6) calculations. Trace inorganic constituents are constituents that occur at concentrations generally less than 0.1 milligrams per liter (mg/l). Major inorganic constituents, as defined herein, are constituents that occur at concentrations generally greater than 0.1 mg/l. Calculations included bicarbonate and nitrate concentrations, total dissolved solids, and an ion balance analysis for major inorganic constituents.

4.2.2 Occurrence of Target Organic Compounds

The target organic compounds for this study have been grouped according to the method of analysis and are listed in Table 4.2-1. The following discussions summarize the analytical results by method and sampling event. The minimum concentrations that are reported in the following sections are concentrations which exceeded the lower detection limit. A tabulated summary of the target organic compound results is provided in Table 4.2-2, which includes the sampling

Table 4.2-1 CMP Surface-Water List of Target Organic Compounds

Organochlorine Pesticide Method
- Aldrin
- Chlordane
- Dieldrin
- Endrin
- Hexachlorocyclopentadiene
- Isodrin
- PPDDE
- PPDDT

Volatile Organohalogen Method
- 1,1-Dichloroethane
- 1,1-Dichloroethene
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane
- 1,2-Dichloroethane
- 1,2-Dichloroethene
- Carbon tetrachloride
- Chlorobenzene
- Chloroform
- Methylene Chloride
- Tetrachloroethene
- Trichloroethene

Organosulfur Compound Method
- 1,4-Dithiane
- 1,4-Oxathiane
- Benzothiazole
- Dimethyldisulfide
- p-Chlorophenylmethylsulfone
- p-Chlorophenylmethylsulfoxide
- p-Chlorophenylmethylsulfide

Organophosphorus Pesticides Compound Method
- Atrazine
- Malathion
- Parathion
- Supona
- Vapona

Volatile Aromatic Method
- Benzene
- Ethylbenzene
- Toluene
- Xylene (m)
- Xylenes (o,p)
- Chlorobenzene

Hydrocarbon Method
- Dicyclopentadiene (DCPD)
- Methylisobutylketone (MIBK)
- Bicycloheptadiene (BCHPD)

Phosphonate Method
- Diisopropylmethylphosphonate (DIMP)
- Dimethyl methyl phosphonate

DBCP Method
- Dibromochloropropane (DBCP)

Acid Extractables (Phenols)
- 2-Chlorophenol
- 2-Methylphenol (2-Cresol)
- 2-Nitrophenol
- 2,4-Dichlorophenol
- 2,4-Dimethylphenol
- 2,4-Dinitrophenol
- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol
- 4-Chloro-3-cresol (3-Methyl-4-chlorophenol)
- 4-Methylphenol (4-Cresol)
- 4-Nitrophenol
- Pentachlorophenol
- Phenol

Table 4.2-2 FY89 Occurrences of Target Organic Compounds in Surface-Water Samples

Sampling Location	Sampling Event*	Target Organic Compound	Concentration ($\mu g/l$)
Irondale Gulch Drainage Basin			
SW01001	Spring	DMMP	1.03
SW01002	Spring	Aldrin	3.20
		Atrazine	85.2
		BTZ	14.2
		Chlordane	9.90
		Chloroform	7.07
		CL6CP	0.221
		CPMSO	750
		CPMSO2	84.0
		DBCP	38.0
		DCPD	96.9
		Dieldrin	2.00
		DMMP	0.742
		Endrin	0.470
		Isodrin	0.740
		Malathion	10.7
		Parathion	15.1
		PPDDT	0.193
		Supona	7.10
		Tetrachloroethene	1.64
		Toluene	4.42
SW01004	Spring	Endrin	0.053
SW02004	Spring	Isodrin	0.097
SW02006	Spring	Chloroform	4.33
		DMMP	2.54
	Fall	Chloroform	4.26
SW07001	Spring	Aldrin	0.152
		CL6CP	0.072
		Dieldrin	0.080
		DMMP	2.08
		Isodrin	0.132
		PPDDE	0.252
		PPDDT	0.064
		Vapona	1.86

Table 4.2-2 FY89 Occurrences of Target Organic Compounds in Surface-Water Samples (Continued)

Sampling Location	Sampling Event*	Target Organic Compound	Concentration (µg/l)
Irondale Gulch Drainage Basin (continued)			
SW07002	Fall	DIMP	0.641
SW11001	Spring	CL6CP	0.710
	Storm	2,4,5-Trichlorophenol	52.0
		Parathion	1.04
		Xylenes (o,p)	1.46
SW11002	Spring	CL6CP	0.259
		DMMP	0.430
SW11003	Spring	Aldrin	0.058
		Chlordane	0.149
		PPDDT	0.055
		Vapona	0.727
SW12003	Spring	Endrin	0.059
SW12004	Spring	4-Methylphenol	4.56
		CPMSO	35.9
	Fall	Atrazine	4.28
		Vapona	0.703
First Creek Drainage Basin			
SW08001	Spring	Vapona	0.788
SW08003	Storm	DBCP	0.241
	Fall	Dieldrin	0.062
		Endrin	0.062
SW24001	Fall	DMMP	0.508
SW24002	Spring	Vapona	0.660

Table 4.2-2 FY89 Occurrences of Target Organic Compounds in Surface-Water Samples (Continued)

Sampling Location	Sampling Event*	Target Organic Compound	Concentration (μg/l)
South Platte Drainage Basin (continued)			
SW36001 (continued)	Spring	Endrin	0.680
		Ethylbenzene	310
		Isodrin	0.455
		MIBK	3200
		Parathion	>50.0
		Phenol	34.9
		PPDDE	0.899
		PPDDT	0.508
		Supona	1.91
		TCLEE	340
		Toluene	140
		TRCLE	270
		Vapona	57.0
		Xylenes (o,p)	520
		Xylene (m)	180
	Fall	112TCE	0.969
		12DCE	8.20
		Aldrin	13.0
		Atrazine	8.06
		BCHPD	10.9
		Benzene	18.6
		Chlordane	8.60
		Chlorobenzene	>200
		Chloroform	128
		CL6CP	0.673
		DBCP	6.23
		DCPD	22.9
		Dieldrin	4.80
		DIMP	0.496
		DMMP	1.70
		Endrin	3.70
		Ethylbenzene	28.8
		Isodrin	1.60
		MIBK	8.77
		PPDDE	0.260
		PPDDT	2.80
		Supona	4.44
		TCLEE	4.47

Table 4.2-2 FY89 Occurrences of Target Organic Compounds in Surface-Water Samples (Continued)

Sampling Location	Sampling Event*	Target Organic Compound	Concentration ($\mu g/l$)
South Platte Drainage Basin (continued)			
SW36001 (continued)	Fall	Toluene	5.79
		TRCLE	20.4
		Vapona	6.29
		Xylenes (o,p)	41.2

* Spring - April 18 through May 18, 1989
Storm - May 10 through May 15, 1989
Fall - September 25 through September 28, 1989
$\mu g/l$ = micrograms per liter

locations within the RMA drainage basins, sampling periods, target organic compounds and concentrations. A geographical representation of the target organic compound detections with respect to RMA drainage basins is provided in Plate 4.2-1. Based on QA/QC criteria twenty volatile organohalogen compound and nine organophosphorus compound analysis were rejected for quantitative and interpretive use. A discussion of the QA/QC protocol and the reasons these samples and other samples were rejected is presented in Section 4.5.

4.2.2.1 Volatile Organohalogens. Compounds in the volatile organohalogen group are listed as follows:

1,1,1-Trichloroethane (111TCE)
1,1,2-Trichloroethane (112TCE)
1,1-Dichloroethane (11DCLE)
1,1-Dichloroethene (11DCE)
1,2-Dichloroethane (12DCLE)
1,2-Dichloroethene (12DCE)
Carbon tetrachloride (CCL4)
Chlorobenzene (CLC6H5)
Chloroform (CHCL3)
Methylene chloride (CH2CL2)
Tetrachloroethene (TCLEE)
Trichloroethene (TRCLE)

Analytical results as reported by the laboratory were acceptable for only six of the 26 volatile organohalogen samples collected during the spring sampling event. The compounds 112TCE, 12DCE, CLC6H5,CHCL3, TCLEE and TRCLE were detected in one sample collected from the South Platte drainage basin (Basin A; SW36001). The concentrations of these compounds were: 12.0 μg/l of 112TCE, 73.0 μg/l of 12DCE, 7500 μg/l of CLC6H5, 940 μg/l of CHCL3, 340 μg/l of TCLEE and 270 μg/l of TRCLE. CHCL3 was detected in two samples collected from the Irondale Gulch drainage basin in the South Plants water tower pond (SW01002; 7.07 μg/l) and in the South Plants steam effluent ditch (SW02006; 4.33 μg/l). TCLEE was detected in one sample collected from the Irondale Gulch drainage basin in the South Plants water tower pond (SW01002; 1.64 μg/l).

Seven samples were collected during storm events and analyzed for organohalogen compounds. There were no detections of these compounds in any of these samples.

The compounds 112TCE, 12DCE, CLC6H5, TCLEE, CHCL3 and TRCLE were detected in one sample collected from the South Platte drainage basin (Basin A; SW36001) during the fall sampling period. The concentrations of these compounds were: 0.969 μg/l of 112TCE, 8.20 μg/l of 12DCE, >200 μg/l of CLC6H5, 4.47 μg/l of TCLEE, 128 μg/l of CHCL3 and 20.4 μg/l of TRCLE. CHCL3 was detected in one sample collected from the Irondale Gulch drainage basin (South Plants steam effluent; SW02006; 4.26 μg/l) during the fall sampling period.

4.2.2.2 Volatile Aromatics. Compounds in the volatile aromatic group are listed as follows:

Benzene (C6H6)
Ethylbenzene (ETC6H5)
m-Xylene (13DMB)
Toluene (MEC6H5)
Xylenes (o,p) (XYLEN)

Two samples that were collected during the spring sampling event detected volatile aromatics. Benzene, ethylbenzene, m-xylene, toluene and xylenes (o,p) were detected in one sample collected from the South Platte drainage basin (Basin A; SW36001) at concentrations of 360 μg/l benzene, 310 μg/l ethylbenzene, 180 μg/l m-xylene, 140 μg/l toluene and 520 μg/l xylenes (o,p). Toluene was detected in one sample collected from the Irondale Gulch drainage basin (South Plants water tower pond; SW01002; 4.42 μg/l).

Seven samples were collected for volatile aromatic analyses during storm events. Xylenes (o,p) were detected in a sample collected from the Irondale Gulch drainage basin (Peoria Interceptor; SW11001; 1.46 μg/l). A sample collected from this location during the spring sampling event did not contain volatile aromatics.

One sample that was collected during the fall sampling event detected volatile aromatics. Benzene, ethylbenzene, toluene and xylenes (o,p) were detected in a sample collected from the South Platte drainage basin (Basin A ;SW36001) at concentrations of 18.6 μg/l benzene, 28.8 μg/l ethylbenzene, 5.79 μg/l toluene and 41.2 μg/l xylenes (o,p).

4.2.2.3 Organosulfur Compounds. Compounds in the organosulfur group are listed as follows:

p-Chlorophenylmethyl sulfide (CPMS)
p-Chlorophenylmethyl sulfoxide (CPMSO)
p-Chlorophenylmethyl sulfone (CPMSO2)

1,4-Dithiane (DITH)
1,4-Oxathiane (OXAT)
Dimethyl disulfide (DMDS)
Benzothiazole (BTZ)

Three samples collected during the spring sampling event detected organosulfur compounds. CPMS, DITH, CPMSO2, CPMSO and DMDS were detected in one sample collected from South Platte drainage basin (Basin A; SW36001) at the following concentrations: 120 $\mu g/l$ CPMS, 1.58 $\mu g/l$ DITH, 160 $\mu g/l$ CPMSO2, CPMSO 73.7 $\mu g/l$ and 1.82 $\mu g/l$ DMDS. BTZ, CPMSO2 and CPMSO were detected in one sample collected from the Irondale Gulch drainage basin (South Plants water tower pond; SW01002). The concentrations were 14.2 $\mu g/l$ BTZ, 84.0 $\mu g/l$ CPMSO2 and 750 $\mu g/l$ CPMSO. CPMSO was detected in one sample also collected from Irondale drainage basin (Storm Sewer; SW12004; 35.9 $\mu g/l$).

Seven samples were collected for organosulfur compound analyses during storm events. Organosulfur compounds were not detected in these samples.

Twelve samples were collected for organosulfur compound analyses during the fall sampling event. Organosulfur compounds were not detected in these 12 samples, including samples from the two sites (SW12004 and SW36001) collected during the spring sampling event that contained organosulfur compounds.

4.2.2.4 Organochlorine Pesticides. Compounds in the organochlorine pesticide group are listed as follows:

Aldrin
Chlordane
Dieldrin
Endrin
Hexachlorocyclopentadiene (CL6CP)
Isodrin
p,p'-DDE (PPDDE)
p,p'-DDT (PPDDT)

Ten samples that were collected during the spring sampling event detected organochlorine pesticides. In the South Platte drainage basin (Basin A; SW36001) one sample contained aldrin at 6.50 $\mu g/l$, chlordane at 64.0 $\mu g/l$, dieldrin at 6.50 $\mu g/l$, endrin at 0.680 $\mu g/l$, CL6CP at 1.00 $\mu g/l$, isodrin at 0.455 μg/l, PPDDE at 0.899 μg/l and PPDDT at 0.508 μg/l. In a First Creek drainage basin sample (First Creek Off-Post; SW37001) chlordane at 0.268 μg/l, dieldrin at 0.0577 μg/l, endrin at 0.0643 μg/l and PPDDT at 0.0571 μg/l were detected. Aldrin was detected in Irondale Gulch drainage basin at South Plants water tower pond (SW01002; 3.20 μg/l), Uvalda Ditch A (SW07001; 0.152 μg/l) and Havana Pond (SW11003; 0.0581 μg/l). Isodrin was detected in Irondale Gulch drainage basin at South Plants water tower (SW01002; 0.740 μg/l), Uvalda Ditch A (SW07001; 0.132 μg/l) and Lake Mary (SW02004; 0.0972 μg/l). PPDDT was detected in the Irondale Gulch drainage basin at South Plants water tower pond (SW01002; 0.193 μg/l), Uvalda Ditch A (SW07001; 0.0638 μg/l) and Havana Pond (SW11003; 0.0552 μg/l). PPDDE was detected in Irondale Gulch drainage basin at Uvalda Ditch A (SW07001; 0.252 μg/l). Chlordane was detected in Irondale Gulch drainage basin at South Plants water tower pond (SW01002; 9.90 μg/l) and Havana Pond (SW11003; 0.149 μg/l). Dieldrin was detected in Irondale Gulch drainage basin at South Plants water tower pond (SW01002; 2.00 μg/l) and Uvalda Ditch A (SW07001; 0.0795). Endrin was detected in Irondale Gulch drainage basin at South Plants water tower pond (SW01002; 0.470 μg/l), Upper Derby Lake (SW01004; 0.0533 μg/l) and Rod and Gun Club Pond (SW12003; 0.0588 μg/l). CL6CP was detected in Irondale Gulch drainage basin at South Plants water tower pond (SW01002; 0.221 μg/l), Uvalda Ditch A (SW07001; 0.0717 μg/l), Peoria Interceptor (SW11001; 0.710 μg/l) and Havana Interceptor (SW11002; 0.259 μg/l).

One sample that was collected during storm events detected organochlorine pesticides. Dieldrin was detected in one sample collected from the Sand Creek drainage basin in a ditch near the Motor Pool (SW04001; 0.0551 μg/l). Although a sample collected from SW11002 during the spring sampling event contained CL6CP, there were no reported detections during the storm sampling event.

Two samples that were collected during the fall sampling event detected organochlorine pesticides. Aldrin, Chlordane, CL6CP, isodrin, dieldrin, endrin, PPDDE and PPDDT were detected in one sample collected from South Platte drainage basin (Basin A; SW36001) at concentrations of 13.0 μg/l aldrin, 8.60 μg/l chlordane, 0.673 μg/l CL6CP, 1.60 μg/l isodrin, 4.80 μg/l dieldrin, 3.70 μg/l endrin, 0.260 μg/l PPDDE and 2.80 μg/l PPDDT. One sample collected from First Creek drainage basin at South First Creek monitoring station (SW08003) detected dieldrin and endrin at 0.0621 μg/l and 0.0625 μg/l respectively. The compounds detected in samples collected from SW07001, SW11001 and SW11002 during the spring sampling event were not detected during the fall sampling event. The compounds detected in a sample collected from SW08003 during this event were not detected during the spring sampling event.

4.2.2.5 Hydrocarbons. Compounds in the hydrocarbon group that were analyzed by the DCPD/MIBK method are listed as follows:

- Bicycloheptadiene (BCHPD)
- Dicyclopentadiene (DCPD)
- Methylisobutylketone (MIBK)

Three samples that were collected during the spring sampling event contained hydrocarbon compounds. BCHPD, DCPD and MIBK was detected in one sample collected from South Platte drainage basin (Basin A; SW36001) with concentrations for BCHPD at 53.4 μg/l, DCPD at 76.7 μg/l and MIBK at 3200 μg/l. DCPD was detected in one sample collected from Irondale Gulch drainage basin (South Plants water tower pond; SW01002; 96.9 μg/l). DCPD was also detected in First Creek drainage basin at the First Creek Off-Post monitoring station (SW37001; 21.1 μg/l).

Hydrocarbon compounds were not detected in samples collected during storm events.

Hydrocarbon compounds were detected in one sample collected during the fall sampling event. BCHPD, DCPD and MIBK were detected in one sample collected from South Platte drainage basin (Basin A; SW36001) at 10.9 μg/l, 22.9 μg/l and 8.77 μg/l concentrations, respectively.

4.2.2.6 Organophosphorus Compounds. Compounds in the nitrogen phosphate pesticides group are listed as follows:

- Atrazine
- Malathion
- Parathion
- Supona
- Vapona

Nine samples that were collected during the spring sampling event detected organophosphorus compounds. In the South Platte drainage basin one sample collected at Basin A monitoring station (SW36001) detected atrazine at 370 μg/l, Vapona at 57.0 μg/l, parathion at >50.0 μg/l and Supona at 1.91 μg/l concentrations. Vapona was detected in four samples obtained from First Creek drainage basin at First Creek South Boundary (SW08001; 0.788 μg/l), North First Creek monitoring station (SW24002; 0.660 μg/l), North Bog (SW24003; 0.635 μg/l) and First Creek near North Plants (SW30002; 0.635 μg/l). Vapona was detected in two samples collected in Irondale Gulch drainage basin at Uvalda Ditch A (SW07001) and Havana Pond (SW11003) at concentrations of 1.86

μg/l and 0.727 μg/l, respectively. Atrazine, malathion, parathion and Supona were also detected in one sample collected from Irondale Gulch drainage basin in the South Plants water tower pond (SW01002) with atrazine at 85.2 μg/l, malathion at 10.7 μg/l, parathion at 15.1 μg/l and Supona at 7.10 μg/l.

One sample that was collected during storm events detected organophosphorus compounds. Parathion was detected in one sample collected from the Irondale Gulch drainage basin (Peoria Interceptor; SW11001) at a concentration of 1.04 μg/l. Parathion was not detected in a sample collected from this location during the spring sampling event.

Organophosphorus compounds were detected in two samples collected during the fall sampling event. Supona, Vapona and atrazine were detected in one sample collected from South Platte drainage basin (Basin A; SW36001) at concentrations of 4.44 μg/l, 6.29 μg/l and 8.06 μg/l, respectively. Atrazine and Vapona were detected in one sample collected from Irondale Gulch drainage basin (Storm Sewer; SW12004) at concentrations of 4.28 μg/l and 0.703 μg/l, respectively. Atrazine and Vapona were not detected in a sample collected from SW12004 during the spring sampling event. Vapona was detected in a sample collected from SW07001 during the spring sampling event but was not detected during the fall sampling event.

4.2.2.7 Phosphonates. Compounds in the phosphonate group are listed as follows:

Diisopropylmethylphosphonate (DIMP)
Dimethylmethylphosphonate (DMMP)

Phosphonate compounds were detected in seven samples collected during the spring sampling event. DIMP was detected in two samples collected from First Creek drainage basin at North Bog (SW24003; 2.06 μg/l) and First Creek Off-Post (SW37001; 88.0 μg/l). DIMP was also detected in one sample obtained from South Platte drainage basin at Basin A monitoring station (SW36001; 4.13 μg/l). DMMP was detected in five samples collected from the Irondale Gulch drainage basin at North Uvalda monitoring station (SW01001; 1.03 μg/l), the South Plants water tower pond (SW01002; 0.742 μg/l), the South Plants steam effluent (SW02006; 2.54 μg/l), Uvalda Ditch A (SW07001; 2.08 μg/l) and Havana Interceptor (SW11002; 0.430 μg/l). DMMP was also detected in South Platte drainage basin at Basin A monitoring station (SW36001; 10.8 μg/l).

Seven samples that were collected during storm events did not contain phosphonates.

Three samples detected phosphonate compounds that were collected during the fall sampling event. DIMP and DMMP were detected in one sample collected from South Platte drainage basin (Basin A; SW36001) at 0.496 μg/l and 1.70 μg/l, respectively. In Irondale Gulch drainage basin DIMP was detected at Uvalda Ditch B (SW07002; 0.641 μg/l) and DMMP was detected at the Sewage Treatment Plant (SW24001; 0.508 μg/l). Samples collected from SW01001, SW02006, SW07001, SW11002 and SW24001 during the spring sampling event contained DMMP, but DMMP was not detected in samples collected from these locations during the fall sampling event.

4.2.2.8 Dibromochloropropane (DBCP). Twenty-six samples were collected for DBCP analysis during the spring sampling event. DBCP was detected in one sample collected from Irondale Gulch drainage basin (South Plants water tower pond; SW01002; 38.0 μg/l) and South Platte drainage basin (Basin A; SW36001; 130 μg/l).

One sample that was collected during a storm event detected DBCP. DBCP was detected in one sample collected from First Creek drainage basin (South First Creek monitoring station; SW08003; 0.241 μg/l). A sample collected from this location during the spring sampling event did not contain DBCP.

One sample that was collected during the fall sampling event detected DBCP. DBCP was detected in one sample obtained from South Platte drainage basin (Basin A; SW36001) at a concentration of 6.23 μg/l.

4.2.2.9 Phenols. Compounds in the phenol group are listed as follows:

2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2-Chlorophenol
2-Methylphenol (2-Cresol)
2-Nitrophenol
4-Chloro-3-cresol (3-Methyl-4-chlorophenol)
4-Methylphenol (4-Cresol)
4-Nitrophenol
Pentachlorophenol
Phenol

Two samples collected during the spring sampling event detected phenols. Three phenol compounds were detected in samples collected from South Platte drainage basin (Basin A; SW36001; 14.6 μg/l 2,4-dichlorophenol, 13.6 μg/l 2-chlorophenol and 34.9 μg/l phenol) and one phenol was detected in Irondale Gulch drainage basin (Storm Sewer; SW12004; 4.56 μg/l 4-methylphenol).

Seven samples collected during the storm events were analyzed for phenols. A single detection of 52.0 μg/l of 2,4,5-trichlorophenol was measured in a sample from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001). A sample collected from this location during the spring sampling event did not contain phenols.

Seven samples collected during the fall sampling event were analyzed for phenols. There were no detections of phenols, including the samples collected from SW12004 and SW36001, which contained phenols during the spring sampling event.

4.2.3 Occurrence of Nontarget Organic Compounds

GC/MS analyses were performed to provide confirmation of CMP target compound analyses and to provide information regarding the potential presence of nontarget compounds at specific locations. Confirmational GC/MS results for CMP target compounds are discussed in Section 4.5. The results of GC/MS analyses for nontarget compounds are discussed below. A list of the nontarget compounds, sampling locations, sampling events and concentrations is provided in Table 4.2-3.

Fifteen samples were collected for GC/MS analyses during the spring sampling event. A single nontarget compound, dichlorobenzene, was detected in a sample collected from South Platte drainage basin (Basin A; SW36001) at a concentration of 7910 μg/l.

Five samples were collected for GC/MS analyses during storm events. Several nontarget compounds were detected in samples from Irondale Gulch drainage basin at the Peoria Interceptor (SW11001), the Havana Interceptor (SW11002) and the South Uvalda (SW12005) monitoring stations. These detected compounds and their respective concentrations are summarized in Table 4.2-3.

Seven samples were collected for GC/MS analyses during the fall sampling event. A single nontarget compound, dichlorobenzene, was detected in a sample collected from South Platte drainage basin at the Basin A monitoring station (SW36001) at a concentration of 290 μg/l.

Table 4.2-3 Occurrence of Nontarget Organic Compounds

Sample Location	Sampling Event*	Compound	Concentration ($\mu g/l$)
Irondale Gulch Drainage Basin			
SW11001	Storm	1-Methylnaphthalene	70
		1,3-Dimethylnaphthalene	100
		1,8-Dimethylnaphthalene	100
		2-Methylnaphthalene	22
		Dodecane	200
		Eicosane	100
		Heptodecane	400
		Hexadecane	300
		Nonadecane	200
		Octadecane	200
		Pentadecane	300
		Phenanthrene	10
		Tetradecane	400
		Tridecane	300
SW11002	Storm	2-Butoxyethanol	19
		2-Cyclohexen-1-ol	5.0
		2-Ethyl-1-hexanol	3.0
		3-Methyl-2-cyclohexen-1-one	3.0
		Hexadecanoic acid	4.0
SW12005	Storm	3-Methyl-2-cyclohexen-1-one	9.0
		Benzaldehyde	4.0
		Benzyl alcohol	2.2
		Hexadecanoic acid	4.0
South Platte Drainage Basin			
SW36001	Spring	Dichlorobenzene	7910
	Fall	Dichlorobenzene	290

$\mu g/l$ = micrograms per liter
* Spring - April 18 through May 18, 1989
Storm - May 10 through May 15, 1989
Fall - September 25 through September 28, 1989

4.2.4 Occurrence of Trace Inorganic Constituents

Trace inorganic constituents analyzed in this study included six trace metals, arsenic and cyanide. Trace metals generally occur in natural waters at concentrations < 0.1 mg/l. Trace metals for which analyses were performed included cadmium, chromium, copper, lead, mercury and zinc. Twenty-six sites were sampled during the spring sampling event, seven sites were sampled during storm events and 12 sites were sampled during the fall event for these constituents. Separate samples were submitted for total recoverable and dissolved fraction analyses during the spring sampling event. Storm event samples were analyzed for the dissolved fraction, and fall event samples were analyzed for total recoverable analytes. The occurrence of trace inorganic constituents in surface-water samples presented in Table 4.2-4. A geographical representation of the trace inorganic constituent detections is provided on Plate 4.2-2.

4.2.4.1 Cadmium, Chromium and Copper. Twenty-six water samples collected during the spring sampling event were analyzed for the dissolved fraction and 24 samples were analyzed for the total recoverable fraction. Detectable concentrations of chromium and copper were not present in the samples. Dissolved and total cadmium were detected once in a sample collected from South Platte drainage basin at Basin A monitoring station (SW36001) with concentrations of 13.5 μg/l and 14.9 μg/l, respectively.

Seven samples were collected during storm events and were submitted for the dissolved fraction trace metal analysis. Detectable concentrations of cadmium and chromium were not present in any samples. Copper was detected once in a sample collected from Irondale Gulch drainage basin in Havana Interceptor (SW11002) at a concentration of 10.5 μg/l.

Twelve samples collected during the fall sampling event were analyzed for the total recoverable fraction. Detectable concentrations of cadmium, chromium and copper were not present in any samples.

4.2.4.2 Arsenic. Twenty-six samples collected during the spring sampling event were analyzed for dissolved arsenic, and 24 samples were analyzed for total recoverable arsenic. Dissolved arsenic was detected in six samples at concentrations ranging from 2.44 μg/l to 280 μg/l. The minimum and maximum concentrations were detected in samples collected from Irondale Gulch drainage basin at Upper Derby Lake (SW01004) and South Platte drainage basin at the Basin A monitoring stations (SW36001), respectively. Total arsenic was detected in three samples at concentrations ranging from 2.61 μg/l to 280 μg/l. The minimum and maximum concentrations were detected in

Table 4.2-4 Occurrence of Trace Inorganic Constituents

Sampling Location	Sampling Event*	Trace Metal	Concentration (μg/l)
Irondale Gulch Drainage Basin			
SW01001	Spring	Zinc (total)	23.8
SW01002	Spring	Arsenic	16.9
		Mercury	0.20
		Zinc	34.8
SW01004	Spring	Arsenic (total)	2.61
		Arsenic	2.44
SW02006	Spring	Mercury (total)	0.13
		Mercury	0.10
	Fall	Arsenic (total)	2.64
		Mercury (total)	0.294
SW07001	Spring	Cyanide	6.25
		Mercury (total)	0.20
		Zinc (total)	68.8
		Zinc	52.7
SW07002	Fall	Arsenic (total)	2.64
SW11001	Storm	Zinc	38.1
SW11002	Storm	Copper	10.5
		Zinc	29.4
SW12001	Spring	Cyanide	6.91
		Zinc	45.7
SW12003	Spring	Arsenic (total)	3.11
		Arsenic	2.77
		Zinc	36.9
SW12004	Spring	Zinc (total)	87.3
		Zinc	35.1
SW12005	Spring	Zinc (total)	64.4
	Storm	Zinc	27.3
	Fall	Arsenic (total)	2.43

Table 4.2-4 Occurrence of Trace Inorganic Constituents (continued)

Sampling Location	Sampling Event*	Trace Metal	Concentration (μg/l)
First Creek Drainage Basin			
SW08001	Spring	Arsenic	2.61
SW08003	Fall	Arsenic (total)	2.83
SW24001	Spring	Arsenic	29.0
	Fall	Arsenic (total)	30.2
Sand Creek Drainage Basin			
SW04001	Storm	Zinc	43.7
South Platte Drainage Basin			
SW36001	Spring	Arsenic (total)	280
		Arsenic	280
		Cadmium (total)	14.9
		Cadmium	13.5
		Zinc	32.7
	Fall	Arsenic (total)	118
		Mercury (total)	0.236

* Spring - April 18 through May 18, 1989
Storm - May 10 through May 15, 1989
Fall - September 25 through September 28, 1989
μg/l - micrograms per liter

samples collected from Irondale Gulch drainage basin at Upper Derby Lake (SW01004) and South Platte drainage basin at Basin A monitoring station (SW36001), respectively.

Seven samples were collected during storm events and were submitted for the dissolved arsenic fraction analysis. Detectable concentrations of arsenic were not present in any samples.

Twelve surface-water samples collected during the fall sampling event were analyzed for total arsenic. Six samples contained reported concentrations ranging from 2.43 μg/l to 118 μg/l. The minimum and maximum concentrations were detected in samples collected from Irondale Gulch drainage basin at South Uvalda monitoring station (SW12005) and South Platte drainage basin at Basin A monitoring station (SW36001), respectively.

4.2.4.3 Zinc. Twenty-six water samples collected during the spring sampling event were analyzed for dissolved zinc, and 24 samples were analyzed for total zinc. Dissolved fraction concentrations were reported in six samples and ranged from 32.7 μg/l to 52.7 μg/l. The minimum and maximum concentrations were detected in samples obtained from South Platte drainage basin (Basin A; SW36001) and Irondale Gulch drainage basin (Uvalda Ditch A; SW07001), respectively. Four samples contained total recoverable concentrations ranging from 23.8 μg/l to 87.3 μg/l. The minimum and maximum concentrations were detected in samples collected from Irondale Gulch drainage basin at the North Uvalda monitoring station (SW01001) and the Storm Sewer (SW12004), respectively.

Seven samples were collected during storm events and were submitted for the dissolved zinc fraction analysis. Four detections were reported at concentrations ranging from 27.3 μg/l to 43.7 μg/l. The minimum and maximum concentrations were detected in samples collected from Irondale Gulch drainage basin at South Uvalda monitoring station (SW12005) and Sand Creek drainage basin in the Motor Pool ditch (SW04001), respectively.

Twelve samples were collected during the fall sampling event and were analyzed for total zinc. Detectable concentrations of zinc were not present in the samples.

4.2.4.4 Mercury. Twenty-six samples collected during the spring sampling event were analyzed for dissolved mercury and 24 samples were analyzed for total mercury. Two detections were reported for each of the dissolved and total mercury analyses. Concentrations ranged from 0.100 μg/l to 0.200 μg/l for dissolved mercury in samples collected from Irondale Gulch drainage basin at the South Plants steam effluent (SW02006) and at Upper Derby Lake (SW01002), respectively. Concentrations ranged from 0.130 μg/l to 0.200 μg/l for total mercury in samples collected from

Irondale Gulch drainage basin at the South Plants steam effluent (SW02006) and in Uvalda Ditch A (SW07001), respectively.

Detectable concentrations of mercury were absent in the seven samples that were collected during storm events.

Twelve samples were collected during the fall sampling event and were analyzed for total recoverable mercury. Two samples that contained reported concentrations of 0.100 μg/l were collected from Irondale Gulch drainage basin at the South Plants steam effluent (SW02006; 0.294 μg/l) and the South Platte drainage basin at Basin A monitoring station (SW36001; 0.236 μg/l).

4.2.4.5 Lead. Twenty-six samples were collected during the spring sampling event and were analyzed for dissolved lead and 24 samples were analyzed for total recoverable lead. Detectable concentrations of either dissolved or total recoverable lead were not present in the samples.

Seven samples were collected during storm events and were submitted for the dissolved lead fraction analysis. Detectable concentrations of lead were not present in the samples.

Twelve samples collected during the fall sampling event were analyzed for total recoverable lead. Detectable concentrations of lead were not present in the samples.

4.2.4.6 Cyanide. A total of 45 samples were submitted for cyanide analysis during the spring, storm and fall sampling events. Two samples collected during the spring sampling event contained concentrations of 5.00 μg/l. The samples were collected from Irondale Gulch drainage basin at Uvalda Ditch A (SW07001; 6.25 μg/l) and Uvalda Ditch C (SW12001; 6.91 μg/l).

4.2.5 Field Parameter Measurements

Field parameters measured for this study included temperature, pH, specific conductance and alkalinity. Field data were collected from 26 sites during the spring sampling event, seven sites during storm events and 12 sites during the fall sampling event. Appendix B-6 presents field water-quality data for each sampling period.

4.2.5.1 pH. For samples that were collected during the spring sampling event pH values ranged from 5.96 to 9.96. The minimum value (5.96) was measured on a sample collected from First Creek drainage basin at the First Creek North Boundary (SW24004). The maximum value

(9.96) was measured on a sample collected from Irondale Gulch drainage basin in Havana Interceptor (SW11002).

For samples obtained during storm events measured pH values ranged from 7.57 to 9.17. The minimum value (7.57) was measured on a sample collected from Irondale Gulch drainage basin at Uvalda Ditch D (SW12002) and the maximum value (9.17) was measured on a sample collected from Sand Creek drainage basin in the Motor Pool ditch (SW04001).

Samples that were collected during the fall sampling event pH values ranged from 7.43 to 8.87. The minimum value (7.43) was obtained on a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001) and the maximum value (8.87) was measured on a Irondale Gulch drainage basin sample collected in Havana Interceptor (SW11002).

4.2.5.2 Specific Conductance. Specific conductance as measured on samples obtained during the spring sampling event ranged from 15 to 1850 micromhos per centimeter (μmhos/cm). The minimum specific conductance value (15 μmhos/cm) was recorded for a sample collected from the Irondale Gulch drainage basin at Peoria Interceptor monitoring station (SW11001) and the maximum value (1850 μmhos/cm) was obtained on a sample collected from First Creek drainage basin at the North Bog (SW24003).

Specific conductance values for surface-water samples collected during storm events ranged from 25 to 750 μmhos/cm. The minimum specific conductance value (25 μmhos/cm) was recorded for a sample collected from Irondale Gulch drainage basin at Uvalda Ditch D (SW12002) and the maximum value (750 μmhos/cm) was recorded for a sample collected from First Creek drainage basin at the North First Creek monitoring station (SW24002).

Specific conductance values for surface-water samples that were collected during the fall sampling event ranged from 130 to 710 μmhos/cm. The minimum value (130 μmhos/cm) was measured on a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001) and the maximum value was recorded for a sample collected from First Creek drainage basin at South First Creek monitoring station (SW08003).

4.2.5.3 Total Alkalinity. Alkalinity is used in this report to indicate total alkalinity as $CaCO_3$, which is defined as the capacity of a sample to neutralize a strong acid. Alkalinity as calculated in this report assumes a titration pH endpoint of 4.5. During field operations, however, titrations to four pH endpoints were measured and reported when the starting pH of the sample was above 8.3. Based on the historical presence of phosphonates at RMA and in accordance with Standard

Method 403 (APHA, 1985), a pH endpoint of 4.5 was used in subsequent calculations of carbonate species.

Twenty-six field alkalinity measurements were obtained during the spring sampling event. The values ranged from 51.0 mg/l to 370 mg/l. The minimum value was reported for samples collected from Irondale Gulch drainage basin at Havana Pond (SW11003) and the Peoria Interceptor monitoring station (SW11001) and the maximum value was reported for a sample collected from South Platte drainage basin at Basin A monitoring station (SW36001).

Twenty-six samples collected during the spring sampling event were submitted to Data Chem Laboratory for total alkalinity analyses. All samples were titrated to an endpoint of pH 3.1. A summary of the laboratory and field results and the percent differences between the two analyses is shown in Table 4.2-5. Thirteen samples had percent differences less than five percent, five samples had percent differences between five and 10 percent, and eight samples had percent differences above 10 percent. The discrepancies between the laboratory and field alkalinities above five percent may be attributable to the presence of noncarbonated contributors to alkalinity, thus increasing the total alkalinity concentration when titration was carried to the endpoint of pH 3.1. Titration endpoints of pH 8.3 and pH 4.5 were not recorded; thus, carbonate and bicarbonate concentrations from the laboratory alkalinities could not be calculated for comparison.

Laboratory alkalinity analyses were performed on the storm and fall events samples. Alkalinity results four storm event samples ranged from 22.9 mg/l to 288 mg/l. The minimum concentration was reported for a sample collected from Sand Creek drainage basin in the Motor Pool ditch (SW04001) and the maximum concentration was reported for a sample collected from First Creek drainage basin at North First Creek monitoring station (SW24002).

Alkalinity concentrations for samples collected during the fall sampling event ranged from 33.8 μg/l to 275 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin in Havana Interceptor (SW11002) and the maximum concentration was also reported for a sample collected from Irondale Gulch drainage basin at Uvalda Ditch A (SW07001).

4.2.6 Occurrence of Major Inorganic Constituents

Major inorganic constituents that naturally occur at concentrations >q mg/l, include calcium, chloride, magnesium, sodium, sulfate, nitrite-nitrate, potassium and fluoride (Appendix B). The

Table 4.2-5 Surface Water Alkalinity Summary of Analytical and Field Results (Spring 1989)

Sampling Location Number	Alkalinity ($\mu g\ CaCO_3/l$) Laboratory Results[a] Endpoint pH 3.1	Alkalinity ($\mu g\ CaCO_3/l$) Field Results[b] Endpoint pH 4.5	Percent Difference Between Lab and Field Alkalinities
Irondale Gulch Drainage Basin			
SW01001	176	174	1.1
SW01002	137	148	-7.4
SW01004	187	186	0.5
SW01005	127	127	0.0
SW02003	125	146	-14.4
SW02004	150	176	-14.8
SW02006	120	129	-7.0
SW07001	146	150	-2.7
SW11001	34.2	51	-32.9
SW11002	51.2	57	-10.2
SW11003	44.9	51	-12.0
SW12001	266	232	12.8
SW12003	309	308	0.3
SW12004	75.4	76	-0.8
SW12005	230	233.4	-1.5
First Creek Drainage Basin			
SW08001	254	268	-5.2
SW08003	281	288	-2.4
SW24001	148	153	-3.3
SW24002	299	311	-3.9
SW24003	173	86	50.3
SW24004	303	1500	-79.8
SW30002	309	287	7.1
SW31001	274	264	3.6
SW31002	286	300	-4.7
SW37001	248	242	2.4
South Platte Drainage Basin			
SW36001	346	370	-6.5

a - Auto-analyzed colorimetric method
b - Sulfuric acid titration

occurrences of each major inorganic constituent in RMA major drainage basins are discussed in this section.

4.2.6.1 Calcium. Twenty-six water samples collected during the spring sampling event were analyzed for the dissolved fraction of calcium, and 24 samples were analyzed for total calcium. The concentrations of the dissolved fraction in samples collected from Irondale Gulch drainage basin ranged from 16.7 mg/l at the Peoria Interceptor (SW11001) to 110 mg/l at the Rod and Gun Club Pond (SW12003) and in First Creek drainage basin at the North Bog (SW24003). The concentrations of total calcium ranged from 15.6 mg/l in a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor station (SW11001) to 110 mg/l in a sample collected from First Creek drainage basin at the North Bog (SW24003).

Samples that were collected during storm events were analyzed for the dissolved fraction of calcium. Results were reported for four samples, with concentrations ranging from 2.00 mg/l to 84.6 mg/l. The minimum and maximum concentrations were detected in samples collected from Irondale Gulch drainage basin at Uvalda Ditch D (SW12002) and First Creek drainage basin at North First Creek monitoring station (SW24002), respectively.

Samples that were collected during the fall sampling event were analyzed for total calcium. The samples contained concentrations and ranged from 21.4 mg/l to 113 mg/l. The minimum and maximum concentrations were detected in samples collected from Irondale Gulch drainage basin South Plants steam effluent (SW02006) and First Creek drainage basin at South First Creek monitoring station (SW08003), respectively.

4.2.6.2 Chloride. Twenty-six samples were collected during the spring sampling event and were analyzed for chloride. The samples contained detectable concentrations that ranged from 5.59 mg/l to 240 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001), and the maximum value was reported for a sample collected from First Creek drainage basin at the North Bog (SW24003).

Samples that were collected at seven locations during storm events were analyzed for chloride. The samples contained detectable concentrations of chloride that ranged from 0.740 mg/l to 48.0 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at Uvalda Ditch D (SW12002) and the maximum concentration was reported for a sample collected from First Creek drainage basin at North First Creek monitoring station (SW24002).

The samples that were collected during the fall sampling event contained detectable concentrations of chloride that ranged from 8.21 mg/l to 86.0 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001) and the maximum concentration was reported for a sample collected from South Platte drainage basin at Basin A monitoring station (SW36001).

4.2.6.3 Fluoride. Twenty-five samples out of 26 samples that were collected during the spring sampling event contained detectable fluoride concentrations ranging from 0.740 mg/l to 2.37 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin in Havana Interceptor (SW11002), and the maximum concentration was reported for a sample collected from First Creek drainage basin at the North Bog (SW24003). A sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001) had a reported concentration that was less than the detection limit (0.48 mg/l).

Three samples that were collected during storm events contained reported fluoride concentrations and ranged from 0.807 mg/l to 1.35 mg/l. These samples were collected from Sand Creek drainage basin in the Motor Pool ditch (SW04001), Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001) and First Creek drainage basin at North First Creek monitoring station (SW24002).

Samples that were obtained during the fall sampling event contained detectable fluoride concentrations that ranged from 0.883 mg/l to 2.14 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin in the Havana Interceptor (SW11002), and the maximum concentration was reported for a sample also collected from Irondale Gulch drainage basin at Uvalda Ditch A (SW07001).

4.2.6.4 Potassium. Twenty-six samples collected during the spring sampling event were analyzed for the dissolved fraction of potassium, and 24 samples were analyzed for total potassium. The concentrations of dissolved potassium ranged from 2.35 mg/l to 12.0 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin in the South Plants steam effluent ditch (SW02006), and the maximum concentration was reported for a sample also collected from Irondale Gulch drainage basin at the Rod and Gun Club Pond (SW12003). Total potassium concentrations ranged from 2.46 mg/l to 12.0 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin in the South Plants steam effluent ditch (SW02006), and the maximum concentration was reported for a sample also collected from Irondale Gulch drainage basin at the Rod and Gun Club Pond (SW12003).

Samples collected during storm events contained dissolved fraction of potassium concentrations ranging from 1.47 mg/l to 6.44 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at Uvalda Ditch D (SW12002), and the maximum concentration was reported for a sample collected from Irondale Gulch drainage basin at the North First Creek monitoring station (SW24002).

The samples obtained during fall sampling event contained detectable total recoverable potassium concentrations that ranged from 2.83 mg/l to 8.57 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin in the South Plants steam effluent ditch (SW02006), and the maximum concentration was reported for a sample also collected from Irondale Gulch drainage basin at the Storm Sewer (SW12004).

4.2.6.5 Magnesium. Twenty-six samples collected during the spring sampling event were analyzed for the dissolved fraction of magnesium, and 24 samples were analyzed for total magnesium. The dissolved fraction concentrations ranged from 1.71 mg/l to 63.5 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin in Havana Pond (SW11003), and the maximum concentration was reported for a sample collected from First Creek drainage basin in the North Bog (SW24003). The total magnesium concentrations ranged from 1.91 mg/l to 62.4 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin in Havana Pond (SW11003), and the maximum concentration was reported for a sample collected from First Creek drainage basin in the North Bog (SW24003).

Dissolved fraction of magnesium results were reported for four samples collected during the fall sampling event and ranged from 0.500 mg/l to 25.0 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at Uvalda Ditch D (SW12002), and the maximum concentration was reported for a sample collected from First Creek drainage basin at North First Creek monitoring station (SW24002).

Twelve samples were collected during the fall sampling event and were analyzed for total magnesium. The samples contained detectable concentrations that ranged from 3.51 mg/l to 34.2. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001), and the maximum concentration was reported for a sample also collected from Irondale Gulch drainage basin at Uvalda Ditch A (SW07001).

4.2.6.6 Sodium. Twenty-six samples collected during the spring sampling event were analyzed for the dissolved fraction of sodium, and 24 samples were analyzed for total sodium. The dissolved fraction concentrations ranged from 9.95 mg/l to 250 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor (SW11001), and the maximum concentration was reported for a sample collected from First Creek drainage basin at the North Bog (SW24003). The total sodium concentrations ranged from 9.64 mg/l to 260 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor (SW11001), and the maximum concentration was reported for a sample collected from First Creek drainage basin at the North Bog (SW24003).

Dissolved fraction of sodium results were reported for four samples that were collected during storm events. The concentrations of these samples ranged from 1.23 mg/l to 88.9 mg/l. The minimum concentration was reported for a sample collected from Sand Creek drainage basin in the ditch near the Motor Pool (SW04001), and the maximum concentration was reported for a sample collected from First Creek drainage basin at North First Creek monitoring station (SW24002).

The samples that were collected during fall event sampling contained total sodium concentrations that ranged from 11.1 mg/l to 110 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001), and the maximum concentration was reported for a sample collected from South Platte drainage basin at Basin A monitoring station (SW36001).

4.2.6.7 Nitrate-Nitrite. Twenty-five out of 26 samples that were collected during the spring sampling event contained nitrite-nitrate concentrations that ranged from 0.052 mg/l to 5.20 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin in Havana Interceptor (SW11002), and the maximum concentration was reported for a sample collected from First Creek drainage basin in a ditch at the First Creek Toxic Yard A sample location (SW31001).

The storm event samples contained nitrite-nitrate concentrations that ranged from 0.190 mg/l to 1.60 mg/l. The minimum concentration was reported for a sample collected from First Creek drainage basin at North First Creek monitoring station (SW24002). The maximum concentration was reported for a sample collected from Irondale Gulch drainage basin at South Uvalda monitoring station (SW12005).

The samples that were collected during the fall sampling event contained nitrite-nitrate concentrations that ranged from 0.051 mg/l to 4.30 mg/l. The minimum concentration was reported for a sample collected from South Platte drainage basin at Basin A monitoring station (SW36001), and the maximum concentration was reported for a sample collected from Irondale Gulch drainage basin at Uvalda Ditch C (SW12001).

4.2.6.8 Sulfate. The samples that were collected during the spring sampling event contained sulfate concentrations that ranged from 22.0 mg/l to 450 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001), and the maximum concentration was reported for a sample collected from First Creek drainage basin at the North Bog (SW24003).

The samples that were collected during storm events contained sulfate concentrations that ranged from 2.49 mg/l to 150 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at Uvalda Ditch D (SW12002), and the maximum concentration was reported for a sample collected from First Creek drainage basin at North First Creek monitoring station (SW24002).

Samples that were collected during the fall sampling event contained sulfate concentrations that ranged from 24.0 mg/l to 150 mg/l. The minimum concentration was reported for a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001), and the maximum concentration was reported for a sample collected from First Creek drainage basin at South First Creek monitoring station (SW08003).

4.2.7 Total Water Chemistry Calculations for Major Inorganic Constituents

Water chemistry calculations that were performed on field and major inorganic constituent results from the spring sampling event are presented below. Calculations include carbonate and bicarbonate concentrations, nitrate, total dissolved solids (TDS) and an ion balance analysis. Table 4.2-6 summarizes these calculations. These calculations provide information for comparative interpretation of the surface-water chemical characteristics of investigative samples and for validation of the analytical and field program results for major inorganic constituents. Calculations were performed on 22 samples for which carbonate system species concentrations could be calculated and for which major inorganic constituent analyses results were available. An explanation of methodologies used in the calculations is also provided.

Table 4.2-6 Calculations for Major Inorganic Constituents in Samples Collected During the Spring Sampling Event

Sampling Location	CO_3 (mg/l)	HCO_3 (mg/l)	NO_3 (mg/l)	TDS (mg/l)	Total Cations (meq/l)	Total Anions (meq/l)	Percent Differences Actual Value (%)	Percent Differences Absolute Value (%)
Irondale Gulch Drainage Basin								
SW01001	12.0	187	3.10	446	6.22	6.28	0.51	0.51
SW01004	NA	227	1.06	484	7.18	6.49	-5.1	5.1
SW01005	12.0	130	0.252	447	5.22	6.59	12	12
SW02003	10.6	157	0.327	437	6.61	6.23	-3.0	3.0
SW02004	34.8	144	0.319	453	6.76	6.87	0.79	0.79
SW02006	19.2	118	0.753	496	5.95	5.87	-0.69	0.69
SW07001	NA	183	14.6	451	6.31	6.24	-0.60	0.60
SW11002	20.4	28.1	0.230	150	2.50	2.31	-3.9	3.9
SW11003	21.6	18.3	1.42	360	6.84	5.61	-9.9	9.9
SW12001	NA	283	15.5	624	9.07	8.27	-4.6	4.6
SW12003	NA	376	1.73	974	14.1	13.5	-2.0	2.0
SW12004	NA	92.7	1.68	212	3.05	2.82	-4.0	4.0
SW12005	18.4	247	13.3	588	8.22	8.27	0.30	0.30
First Creek Drainage Basin								
SW08001	18.0	290	0.456	589	7.97	8.21	1.4	1.4
SW08003	NA	351	1.24	654	8.79	8.73	-0.30	0.30
SW24002	13.2	352	0.387	894	12.2	12.6	1.7	1.7
SW24003	15.6	73.2	1.06	1210	21.7	18.0	-9.3	9.3
SW24004	NA	183	0.350	734	12.8	9.64	-14	14
SW31001	4.80	312	23.0	703	9.54	9.71	0.85	0.85
SW31002	NA	366	0.339	764	10.2	10.4	1.2	1.2
SW37001	19.2	256	(LT) 0.0443	1100	17.2	15.3	-5.9	5.9
South Platte Drainage Basin								
SW36001	NA	451	0.284	855	11.6	11.8	0.81	0.81
Minimum	4.80	18.3	(LT) 0.0443	150	2.50	2.31	-14.0	0.30
Maximum	34.8	451	23.0	1210	21.7	18.0	11.6	14

CO_3 = Carbonate
HCO_3 = Bicarbonate
NO_3 = Nitrate
TDS = Total Dissolved Solids
meq/l = Milliequivalent per liter
mg/l = Milligrams per liter
LT = Less than the CRL
NA = pH less than 8.3
% = percent

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4.2.7.1 Carbonate System Species. The contribution of carbonate species to an aqueous system is dependent on the pH of that system. Phenolphthalein and total alkalinity are terms that relate to the acid-neutralizing capacity of the aqueous system caused by the presence of carbonate and bicarbonate ions. Phenolphthalein and total alkalinity are measured, and the carbonate species are then calculated according to the relative results. For example, waters with pH less than 8.3 have no phenolphthalein alkalinity, and the bicarbonate concentration (as $CaCO_3$) is the total alkalinity (American Public Health Association, 1985). The actual bicarbonate concentration (in mg/l) in waters with pH less than 8.3 is a factor of 1.22 higher than the total alkalinity to account for the stoichiometric conversion from $CaCO_3$ to bicarbonate. In this study, nine samples had a measured pH less than 8.3, and the corresponding bicarbonate concentrations were calculated. Waters with pH greater than 8.3 have a phenolphthalein alkalinity and a total alkalinity. The concentration of the carbonate species is dependent on the magnitude of the two alkalinities. In this study, the phenolphthalein alkalinity was less than one-half the total alkalinity, and the calculation of the carbonate species was as follows:

$$[CO_3^{=}] = (2 \times P) \times 0.60$$
$$[HCO_3^{-}] = (T - 2 \times P) \times 1.22$$

where $[CO_3^{=}]$ is the concentration of the carbonate ion, P is the phenolphthalein alkalinity, 0.60 is the stoichiometric conversion factor for carbonate, $[HCO_3^{-}]$ is the concentration of the bicarbonate ion, T is the total alkalinity, and 1.22 is the stoichiometric conversion factor for bicarbonate. Thirteen samples had measured pH values greater than 8.3, and the corresponding carbonate and bicarbonate calculations were performed.

The results of the calculations for the carbonate system species are shown in Table 4.2-6. Four samples had a measured pH greater than 8.3, but the phenolphthalein alkalinity was not measured in the field and accurate carbonate and bicarbonate ion concentrations could not be calculated. The samples were from the following sites: SW01002, SW11001, SW24001 and SW30002. Calculated carbonate concentrations ranged from 4.80 mg/l to 34.8 mg/l. The minimum value of 4.80 mg/l corresponds to a sample collected from First Creek drainage basin at First Creek Toxic Yard A (SW31001), and the maximum value of 34.8 mg/l corresponds to a sample collected from Irondale Gulch drainage basin at Lake Mary (SW02004). Calculated bicarbonate concentrations ranged from 18.3 mg/l to 451 mg/l. The minimum value of 18.3 mg/l corresponds to a sample collected from Irondale Gulch drainage basin at Havana Pond (SW11003), and the maximum value of 451 mg/l corresponds to a sample collected from South Platte drainage basin at Basin A monitoring station (SW36001).

4.2.7.2 Nitrate. To calculate total dissolved solids (TDS), nitrate concentrations were calculated for the 22 samples referenced above. Nitrate-nitrite (as N) analytical data were converted to milligrams per liter of nitrate on the assumption that nitrite concentrations were negligible. Hem (1985) reported that nitrite is seldom present in concentrations high enough to noticeably influence ionic balance tabulations. Nitrate was calculated by applying a multiplication factor of 4.43 to the nitrate-nitrite (as N) data. This factor is the quotient of the molecular weight of nitrate divided by the molecular weight of nitrogen. Calculated nitrate concentrations ranged from < 0.0443 mg/l to 23.0 mg/l and are reported in Table 4.2-6. The minimum and maximum values correspond to samples collected from First Creek drainage basin at First Creek Off-Post monitoring station (SW37001) and First Creek Toxic Yard A (SW31001), respectively. The calculated value of <0.0443 mg/l is for a nitrate-nitrite result that was less than the CRL of 0.010 mg/l. For the calculation of TDS, the value of 0.04 mg/l was used.

4.2.7.3 Total Dissolved Solids. TDS values for the samples were calculated using dissolved major cation data and anion data. Cation data included in these calculations were calcium, sodium, potassium and magnesium. Anion data included chloride, fluoride, sulfate, bicarbonate and calculated nitrate. Table 4.2-6 indicates that calculated TDS concentrations ranged from 150 mg/l to 1210 mg/l for the 22 samples used in these calculations. The minimum TDS concentration corresponds to a sample collected from Irondale Gulch drainage basin in the Havana Interceptor (SW11002), and the maximum TDS concentration corresponds to a sample collected from First Creek drainage basin at the North Bog (SW24003).

4.2.7.4 Ion Balance Calculations. Ion balance calculations are based on principles of electroneutrality for which a balance of molar concentrations of positively and negatively charged ionic species can be derived. Ion balance calculations consist of converting major inorganic constituent results to milliequivalents per liter (meq/l), summing the cation and anion fractions, and statistically comparing the results. Parameters used in performing ion balance calculations included reported concentrations for calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, nitrate, pH and bicarbonate.

A summary of the ion balance calculations is shown in Table 4.2-6. Complete information on ion balance calculations is provided in Appendix B-5. Summary Table 4.2-6 shows the cation and anion totals for each sample in meq/l and the percent difference between these totals. Percent differences are known as the "charge-balance error," commonly expressed as the difference between the anion and cation totals divided by the sum total (Freeze and Cherry, 1979). The actual charge-balance error and the absolute value of the calculated charge-balance error are listed for each sample. The charge-balance error indicates the magnitude and direction of deviation between cation and anion species, with positive numbers representing samples in which the anion total exceeds the cation total. A review of the actual values for the charge-balance error listed in Table 4.2-6 indicates that the anion total exceeded the cation total in nine samples and that the cation total exceeded the anion total in 13 samples. The absolute value of the charge-balance error indicates the magnitude of the difference between the two totals.

A criterion of less than five percent is generally accepted as indicative of favorable analytical results with respect to the absolute charge-balance error (Freeze and Cherry, 1979). Ion balance calculations indicate that a majority of sample results meet this criteria. Sixteen samples had absolute charge-balance errors that were less than five percent. Of the remaining ion balance calculations, four samples had absolute charge-balance errors between five and 10 percent, and two samples had charge-balance errors greater than 10 percent. Five of these samples had negative charge-balance error values, indicating that the sum of cations exceeded the sum of anions. Charge-balance error values for samples SW01005, SW11003, SW24003 and SW24004 were above 6 percent and were assumed to be indicative of analytical error.

Ion balance calculations were used to cross-check database values and field results. Initial ion balance calculations indicated an anion sum problem for samples SW12005 and SW24004. Upon comparing the database and field notes, it was discovered that alkalinity titration values of an order of magnitude larger (as a result of the titrant concentration) had been entered for sample SW12005 and that it was the most plausible explanation for the elevated concentration of bicarbonate in sample SW24004. Ion balances were recalculated for both samples, resulting in percent difference values that were comparable to the other results.

4.2.8 Comparison of Total and Dissolved Inorganic Analyses

This section provides a comparison of total and dissolved inorganic analyses for samples collected during the spring sampling event. This comparison consists of calculating the percent difference between total and dissolved inorganic constituent results for each case in which values were reported for both analyses. Cases in which either total or dissolved values are available but the complementary value is below the CRL were not included in the calculations performed. These values will be discussed qualitatively. Table 4.2-7 provides a statistical comparison of the total versus dissolved results for RMA surface-water inorganic constituents.

The distribution of percent differences was based on five categories representing the concentrations of the dissolved (D) and total (T) recoverable inorganic constituents. Two categories

Table 4.2-7 Summary of Dissolved Versus Total Recoverable Inorganic Constituent Analyses

Parameter	Number of Sample Pair Analyses Compared	Distribution of Percent Difference[a] (Number of Analyses Meeting Criteria)				
		D < T < 5%	D < T > 5%	T < D < 5%	T < D > 5%	D = T
Arsenic	2	-	2	-	-	-
Cadmium	1	-	1	-	-	-
Mercury	1	-	1	-	-	-
Zinc	2	-	2	-	-	-
Calcium	24	6	5	10	2	1
Magnesium	24	8	8	5	1	2
Potassium	24	11	8	1	3	1
Sodium	24	10	4	5	1	4
	Totals	35	31	21	7	8

D = dissolved fraction
T = total recoverable inorganics
<5% = less than five percent
>5% = greater than five percent

[a] The percent difference between dissolved and total concentration, defined as the absolute value of the difference between dissolved and total concentrations divided by the dissolved concentration.

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distinguish whether the dissolved concentration is less than the total concentration by less than five percent or greater than five percent. Two categories distinguish whether the total concentration is less than the dissolved concentration by less than five percent on greater than five percent. The fifth category represents dissolved concentrations that equal total concentrations.

The majority of the results fall into the category in which the dissolved concentration was less than the total recoverable concentration by less than five percent. Twenty-one sample pair results fall into the category in which the total recoverable concentrations are less than the dissolved concentrations by less than five percent. These results are generally attributed to typical analytical variability. Thirty-one sample pair results fall into the category in which the dissolved fraction is less than the total recoverable concentration by more than five percent. These results may be caused by suspended sediments in the sample. In seven sample pairs, the dissolved fraction was more than five percent greater than the total recoverable inorganic constituents. These results are assumed to be the result of analytical variability or sampling procedures. In eight sample pairs, the concentration of the dissolved fraction equalled the total recoverable concentration.

4.2.8.1 Trace Metal Inorganic Analytes. Six dissolved and total analyte sample pairs were evaluated for percent differences for arsenic, cadmium, mercury and zinc. The absolute value of percent difference between dissolved and total trace analytes ranges from 7.0 to 150 percent. The maximum percent difference was observed for the zinc analysis of sample SW12004, where the total concentration was 87.3 μg/l and the dissolved fraction concentration was 35.1 μg/l.

In the majority of samples analyzed for trace metal analytes, the concentrations were below the CRL and no comparison could be made. All of the analyses compared fall into the category in which the total concentration exceeded the dissolved concentration by more than five percent, which may be attributable to suspended sediments.

4.2.8.2 Major Inorganic Analytes. Ninety-six dissolved and total analyte sample pairs were evaluated for percent differences for calcium, magnesium, potassium and sodium. The absolute value of the percent difference values ranged from 0 to 16 percent. Fifty-six sample pairs had percent difference values in the range of 0.1 to 5 percent, and 32 had percent difference values that were greater than five percent. Eight sample pairs had a percent difference of 0 percent, indicating that the dissolved fraction equaled the total concentration.

Total magnesium and potassium concentrations in eight sample pairs were greater than the dissolved fractions by more than five percent. This relationship also existed for five calcium pairs and four sodium sample pairs.

The percent differences in which the total analyte concentration was less than the dissolved fraction by more than five percent ranged from 6.0 to 9.1 percent. The affected analytes and corresponding sample locations are as follows: calcium: SW11001 and SW12003; magnesium: SW30002; potassium: SW12005, SW30002 and SW36001; and sodium: SW30002.

4.3 Sediment Transport

This section presents the Water Year 1989 results for suspended sediment quantity and bed load or bottom sediment quality at RMA. Total suspended sediment analyses were performed on nine samples during Water Year 1989. Analyses of stream bottom sediment quality were performed on 17 samples collected during the spring sampling event and five samples collected during the fall sampling event. These are listed on Table 3.2-1. Sediment samples were obtained at surface-water quality locations and are shown on Plate 1.3-2. QA/QC and GC/MS confirmational analytical results for stream sediment samples are presented in Section 4.5.

4.3.1 Sediment Quantity

Total suspended solids (TSS) samples were collected during the spring, storm and fall sampling events. Two TSS samples acquired in the spring and during storm events were collected directly into a sample container. Three TSS samples obtained in the fall were acquired with a DH-48 hand-held sampler. Instantaneous discharge measurements were also taken in conjunction with the TSS sampling at most of the sampling sites. Results of the TSS analysis, performed by Data Chem Laboratory are summarized in Table 4.3-1.

TSS concentrations were below detection limits in four of the nine samples collected. Two samples that were obtained during the spring sampling event had TSS concentrations below the CRL (4.00 mg/l), South Plants water tower pond (SW01002) and the Sewage Treatment Plant (SW24001). For samples collected during storm events, TSS concentrations were 5.00 mg/l at North First Creek monitoring station (SW24002), 52.0 mg/l at South First Creek monitoring station (SW08003), 62.0 mg/l at Uvalda Ditch D (SW12002) and 672 mg/l at the Motor Pool (SW04001). During the fall sampling event, TSS concentrations were below the CRL (4.00 mg/l) in samples from two of three sites along the southern reach of First Creek. The single detection of 5.00 mg/l was measured at SW08004 in First Creek near the habitat pond, where First Creek flow ended at this time of year.

Table 4.3-1 FY89 Total Suspended Solids Analytical Results

Sampling Location	Location Name	Sampling Event*	Date	Total Suspended Solids (mg/l)	Flow Rate (cfs)
Irondale Gulch Drainage Basin					
SW01002	South Plants Water Tower Pond	Spring	05/18/89	<4.00	Stagnant
SW12002	Uvalda Ditch D	Storm	05/15/89	62.0	Moderate flow
First Creek Drainage Basin					
SW08001	South First Creek Boundary	Fall	09/29/89	<4.00	0.14
SW08003	South First Creek	Storm	05/14/89	52.0	6.40
		Fall	09/29/89	<4.00	0.10
SW08004	South First Creek (N)	Fall	09/29/89	5.00	0.04
SW24001	Sewage Treatment Plant	Spring	04/21/89	<4.00	0.006
SW24002	North First Creek	Storm	05/15/89	5.00	3.35
Sand Creek Drainage Basin					
SW04001	Motor Pool	Storm	05/15/89	672	Moderate flow

cfs = cubic feet per second
mg/l = milligrams per liter
< = below detection limits

* Spring - April 18 through May 18, 1989
Storm - May 10 through May 15, 1989
Fall - September 25 through September 28, 1989

4.3.2 Sediment Quality

Stream bottom or bed load sediment samples were collected at 17 sites during the spring sampling event and at five sample locations during the fall. Table 3.2-1 lists the sites from which bottom sediments were collected during Water Year 1989. Table 3.2-2 summarizes analytical sediment methods that were used by DataChem and ES&E laboratories.

The distributions of target organic compound and trace inorganic constituent detections during the spring and fall 1989 sampling events are discussed below. The minimum concentrations that are reported in this section are for concentrations that exceed the CRL. Target organic compound detections are summarized in Table 4.3-2, and target trace inorganic compound detections are summarized in Table 4.3-3. Plate 4.3-1 shows the geographic distribution of target organic compounds and trace inorganic compounds that were found on RMA during the spring and fall 1989.

4.3.2.1 Organic Compounds. The most abundant organic compound detected in stream bottom sediments was the organophosphorus pesticide compound atrazine. Atrazine was detected in 15 of 17 samples analyzed during the spring sampling event and was not detected in the five samples analyzed during the fall sampling event. During the spring the maximum concentration of 15.7 μg/g was detected in a sample collected from First Creek drainage basin in First Creek near North Plants (SW30002). During the spring a minimum atrazine concentration of 0.303 μg/g was also detected in a sample collected from First Creek drainage basin at the First Creek Toxic Yard B location (SW31002). During the spring atrazine was also detected in samples collected in the Irondale Gulch and South Platte drainage basins.

The organophosphorus pesticide compounds Vapona and parathion were detected in stream bottom sediments during the spring sampling event. Organophosphorus pesticides were not detected in any of the samples collected during the fall sampling event. Vapona was detected in 2 of 17 samples and parathion was detected in 1 of 17 samples. Detections of Vapona at concentrations of 3.80 μg/g and 0.388 μg/g were found at the Storm Sewer location (SW12004) in Irondale Gulch drainage basin and at First Creek Toxic Yard B location (SW31002) in First Creek drainage basin, respectively. The sample collected from the Storm Sewer (SW12004) also contained 0.472 μg/g parathion.

Only one organosulfur compound CPMSO was detected in 7 of 17 sediment samples collected during the spring sampling event. The maximum CPMSO concentration of 390 μg/g was detected

Table 4.3-2 FY89 Target Organic Compound Detections in Stream Bottom Sediment Samples

Sampling Location	Sampling Event*	Compound	Concentration (μg/g)
Irondale Gulch Drainage Basin			
SW01001	Spring	Atrazine	1.00
SW01002	Spring	Aldrin	8.40
		DBCP	0.029
		Dieldrin	0.400
		Isodrin	0.280
		PPDDE	0.061
		PPDDT	0.160
SW02006	Spring	Atrazine	6.23
		DBCP	0.020
	Fall	BTZ	3.55
		Aldrin	3.00
		Dieldrin	3.50
		Endrin	0.280
		Isodrin	0.060
SW07001	Spring	Atrazine	2.94
		DBCP	0.014
SW11001	Spring	111TCE	0.336
		Atrazine	4.58
		CPMSO	35.0
		DBCP	0.023
		Toluene	0.375
SW11002	Spring	Atrazine	3.72
		CPMSO	5.94
SW12003	Spring	Atrazine	0.885
		CPMSO	23.8
SW12004	Spring	Atrazine	12.0
		CPMSO	390
		Parathion	0.472
		Vapona	3.80
SW12005	Spring	Atrazine	3.00
		CPMSO	>20.0
	Fall	Dieldrin	0.007
		DMMP	0.534

Table 4.3-2 FY89 Target Organic Compound Detections in Stream Bottom Sediment Samples (Continued)

Sampling Location	Sampling Event*	Compound	Concentration ($\mu g/g$)
First Creek Drainage Basin			
SW08001	Spring	Atrazine	2.29
		CPMSO	6.88
SW08003	Spring	Atrazine	10.3
		Fluoroacetic acid	9.40
	Fall	Dieldrin	0.032
SW30002	Spring	Atrazine	15.7
		CPMSO	5.40
SW31001	Spring	Atrazine	4.55
		Dieldrin	0.019
		Endrin	0.019
SW31002	Spring	Atrazine	0.303
		Vapona	0.388
SW37001	Spring	Atrazine	3.42
South Platte Drainage Basin			
SW36001	Spring	m-Xylene	0.949
		Atrazine	13.0
		Benzene	0.281
		Chlorobenzene	10.7
		DBCP	0.170
		Ethylbenzene	0.580
		Tetrachloroethene	1.00
		Toluene	0.561
		Xylenes (o,p)	2.10
	Fall	Aldrin	37.0
		Dieldrin	18.0
		Endrin	18.0
		Isodrin	3.30

* Spring - April 18 through May 18, 1989
Fall - September 25 through September 28, 1989
$\mu g/g$ = micrograms per gram

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in a sample collected from Irondale Gulch drainage basin at the Storm Sewer sample location (SW12004). The minimum CPMSO concentration of 5.40 $\mu g/g$ was detected in samples collected from Irondale Gulch drainage basin in Havana Interceptor (SW11002) and in First Creek drainage basin in First Creek near North Plants (SW30002). CPMSO was not detected above the CRL in South Platte drainage basin at Basin A monitoring station (SW36001) during the spring sampling event. One organosulfur compound, BTZ was detected in one of five samples collected during the fall sampling event. BTZ was detected in Irondale Gulch drainage basin in the South Plants steam effluent ditch (SW02006) at a concentration of 3.55 $\mu g/g$.

Volatile organohalogen compounds were detected in 2 of 17 spring samples and was not detected in any of the fall samples. A sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001) contained 0.336 $\mu g/g$ 111TCE. A sample collected from South Platte drainage basin at Basin A monitoring station (SW36001) contained 10.7 $\mu g/g$ CLC6H5 and 1.00 $\mu g/g$ TCLEE.

Volatile aromatic compounds benzene, ethylbenzene, m-xylene and xylenes (o,p) were detected in 1 of 17 sediment samples collected during the spring sampling event. Volatile aromatic compounds were not detected in any of the five samples collected during the fall. A sample collected from South Platte drainage basin at Basin A monitoring station (SW36001) contained 0.281 $\mu g/g$ benzene, 0.580 $\mu g/g$ ethylbenzene, 0.949 $\mu g/g$ m-xylene and 2.10 $\mu g/g$ xylenes (o,p). Toluene was detected in 2 of 17 sediment samples collected during the spring sampling event. A sample collected from South Platte drainage basin at Basin A monitoring station (SW36001) contained 0.561 $\mu g/g$ toluene, and a sample collected from Irondale Gulch drainage basin at the Peoria Interceptor monitoring station (SW11001) contained 0.375 $\mu g/g$ toluene.

Organochlorine pesticides aldrin, isodrin, PPDDE and PPDDT were detected in 1 of 17 sediment samples collected during the spring sampling event. A sample collected from Irondale Gulch drainage basin at the South Plants water tower pond (SW01002) contained 8.40 $\mu g/g$ aldrin, 0.280 $\mu g/g$ isodrin, 0.0610 $\mu g/g$ PPDDE and 0.160 $\mu g/g$ PPDDT. The organochlorine pesticide endrin was detected in 1 of 17 sediment samples collected during the spring sampling event. A sample collected from First Creek drainage basin at the First Creek Toxic Yard A location (SW31001) contained 0.0188 $\mu g/g$ endrin. The organochlorine pesticide dieldrin was detected in 2 of 17 sediment samples collected during the spring sampling event. Samples collected from Irondale Gulch drainage basin in the South Plants water tower pond (SW01002) and First Creek drainage basin at First Creek Toxic Yard A location (SW31001) contained 0.400 and 0.0188 $\mu g/g$ dieldrin, respectively.

The organochlorine pesticide, dieldrin, was detected in four of five samples collected during the fall sampling event. Organochlorine pesticides aldrin, endrin and isodrin were detected in two of five samples collected during the fall. Dieldrin was detected in Irondale Gulch drainage basin in the South Plants steam effluent ditch (SW02006) and at South Uvalda monitoring station (SW12005) at concentrations of 3.50 $\mu g/g$ and 0.007 $\mu g/g$, respectively. In First Creek drainage basin dieldrin was detected at the South First Creek monitoring station (SW08003) at a concentration of 0.032 $\mu g/g$. In South Platte drainage basin at the Basin A monitoring station (SW36001) dieldrin was detected at a concentration of 18.0 $\mu g/g$. In Irondale Gulch drainage basin aldrin, endrin and isodrin were detected in the South Plants steam effluent ditch at concentrations of 3.00 $\mu g/g$, 0.280 $\mu g/g$ and 0.060 $\mu g/g$, respectively. At Basin A monitoring station (SW36001) in the South Platte drainage basin aldrin, endrin and isodrin were detected at concentrations of 37.0 $\mu g/g$, 18.0 $\mu g/g$ and 3.30 $\mu g/g$, respectively.

DBCP was detected in 4 of 9 sediment samples collected from Irondale Gulch drainage basin during the spring sampling event. The maximum concentration of 0.029 $\mu g/g$ was measured in a sample collected in the South Plants water tower pond (SW01002). The minimum concentration of 0.0140 $\mu g/g$ was measured in a sample collected at Uvalda Ditch A (SW07001). DBCP was not detected in seven sediment samples collected from First Creek drainage basin during the spring sampling event. In South Platte drainage basin at Basin A monitoring station (SW36001) DBCP was detected at a concentration of 0.170 $\mu g/g$ during the spring sampling event. DBCP was not detected in any of the fall samples.

The phosphonate compound, DMMP, was detected in one of five samples collected during the fall sampling event. DMMP was detected at a concentration of 0.534 $\mu g/g$ in a sample collected from Irondale Gulch drainage basin at South Uvalda monitoring station (SW12005).

Fluoroacetic acid was detected in only 1 of 17 sediment samples collected during the spring sampling event. A sample collected from First Creek drainage basin at South First Creek monitoring station (SW08003) contained 9.40 $\mu g/g$ fluoroacetic acid. It was not detected in any of the fall samples.

4.3.2.2 Inorganic Constituents. Stream bottom sediment samples were collected from 17 sites during the spring sampling event and five locations during the fall sampling event and were analyzed for the trace elements arsenic, mercury, cadmium, chromium, copper, lead and zinc. The spring and fall sampling event detections of these constituents in bottom sediments are summarized in Table 4.3-3 and shown on Plate 4.3-1.

Table 4.3-3 FY89 Trace Inorganic Constituent Detections in Stream Bottom Sediment Samples

Sampling Location	Sampling Event*	Compound	Concentration ($\mu g/g$)
Irondale Gulch Drainage Basin			
SW01001	Spring	Zinc	27.4
SW02006	Spring	Chromium	13.7
		Copper	78.8
		Mercury	8.00
		Lead	74.7
		Zinc	159
	Fall	Mercury	4.90
SW07001	Spring	Copper	17.5
		Lead	32.2
		Zinc	63.4
SW11001	Spring	Chromium	9.99
		Copper	14.5
		Lead	27.4
		Zinc	102
SW11002	Spring	Lead	18.1
		Zinc	64.7
SW12003	Spring	Arsenic	4.67
		Cadmium	1.71
		Chromium	15.9
		Copper	19.2
		Lead	119
		Zinc	77.5
SW12004	Spring	Copper	12.0
		Lead	37.0
		Zinc	89.2
SW12005	Spring	Zinc	56.1
	Fall	Arsenic	1.23

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Table 4.3-3 FY89 Trace Inorganic Constituent Detections in Stream Bottom Sediment Samples (Continued)

Sampling Location	Sampling Event*	Compound	Concentration (μg/g)
<u>First Creek Drainage Basin</u>			
SW08001	Spring	Zinc	22.4
SW24002	Spring	Chromium	12.8
		Copper	11.5
		Lead	19.9
		Zinc	45.4
SW31001	Spring	Chromium	11.8
		Copper	10.5
		Zinc	43.2
SW31002	Spring	Chromium	13.1
		Copper	11.7
		Lead	18.7
		Zinc	49.4
SW37001	Spring	Copper	9.11
		Zinc	41.2
<u>South Platte Drainage Basin</u>			
SW36001	Spring	Arsenic	44.0
		Cadmium	1.93
		Copper	12.9
		Mercury	0.500
		Lead	103
		Zinc	60.1
	Fall	Mercury	0.570
		Arsenic	19.0

* Spring - April 18 through May 18, 1989
Fall - September 25 through September 28, 1989
μg/g = micrograms per gram

Arsenic and cadmium were detected in 2 of 17 sediment samples collected during the spring sampling event. A sample collected from South Platte drainage basin at Basin A monitoring station (SW36001) contained 44.0 $\mu g/g$ arsenic and 1.93 $\mu g/g$ cadmium. A sample collected from Irondale Gulch drainage basin in the Rod and Gun Club Pond (SW12003) contained 4.67 $\mu g/g$ arsenic and 1.71 $\mu g/g$ cadmium. Arsenic was detected in two of five samples collected during the fall. Arsenic was detected at a concentration of 1.23 $\mu g/g$ in Irondale Gulch drainage basin at the South Uvalda monitoring station (SW12005). In the South Platte drainage basin at the Basin A monitoring station (SW36001) arsenic was detected at a concentration of 19.0 $\mu g/g$.
Mercury was detected in 2 of 17 sediment samples collected during the spring sampling event. Samples collected from Irondale Gulch drainage basin in the South Plants steam effluent ditch (SW02006) and South Platte drainage basin at Basin A monitoring station (SW36001) contained 8.00 and 0.500 $\mu g/g$ mercury, respectively. Mercury was detected in two of five samples collected during the fall sampling event. Mercury was detected in Irondale Gulch drainage basin in the South Plants steam effluent ditch (SW02006) at a concentration of 4.90 $\mu g/g$. In the South Platte drainage basin at Basin A monitoring station (SW36001) mercury was detected at a concentration of 0.570 $\mu g/g$.

Chromium was detected in 3 of 9 sediment samples collected from Irondale Gulch drainage basin during the spring sampling event. The maximum concentration of 15.9 $\mu g/g$ was detected in a sample collected in the Rod and Gun Club Pond (SW12003). The minimum concentration of 9.99 $\mu g/g$ was detected in a sample collected at the Peoria Interceptor monitoring station (SW11001). Chromium was detected in 3 of 7 samples collected from First Creek drainage basin during the spring sampling event. A maximum concentration of 13.1 $\mu g/g$ was detected at First Creek Toxic Yard B location (SW31002) and the minimum concentration of 11.8 $\mu g/g$ was detected at First Creek Toxic Yard A location (SW31001). Chromium was not detected in South Platte drainage basin. Chromium was not detected in any of the samples collected during the fall sampling event.

Copper was detected in 10 of 17 sediment samples collected during the spring sampling event and was not detected in any of the samples collected during the fall. The maximum concentration of 78.8 $\mu g/g$ was detected in a sample collected from Irondale Gulch drainage basin in the South Plants steam effluent ditch (SW02006). The minimum concentration of 9.11 $\mu g/g$ was detected in a sample collected from First Creek drainage basin at the First Creek Off-Post monitoring station (SW37001). Copper was also detected in the South Platte drainage basin at Basin A monitoring station (SW36001) at a concentration of 12.9 $\mu g/g$.

Lead was detected in 9 of 17 sediment samples collected during the spring sampling event and was not detected in any of the samples collected during the fall. The maximum concentration of

119 $\mu g/g$ was detected in a sample collected from Irondale Gulch drainage basin in the Rod and Gun Club Pond (SW12003). The minimum concentration of 18.1 $\mu g/g$ was detected in a sample also collected from Irondale Gulch drainage basin in Havana Interceptor (SW11002). Lead was also detected in First Creek and South Platte drainage basins.

Zinc was detected in 15 of 17 sediment samples collected during the spring sampling event and was not detected in any of the samples collected during the fall sampling event. The maximum concentration of 159 $\mu g/g$ was detected in a sample obtained from Irondale Gulch drainage basin in the South Plants steam effluent ditch (SW02006). The minimum concentration of 22.4 $\mu g/g$ was detected in a sample collected from First Creek drainage basin at the South First Creek Boundary location (SW08001). Zinc was detected at a concentration of 60.1 $\mu g/g$ in the South Platte drainage basin at the Basin A monitoring station (SW36001).

4.4 Surface-Water/Ground-Water Interaction

It is important to understand the surface-water and ground-water interaction on RMA in order to accurately assess contaminant migration on and off RMA. A comparison of well, lake and stream water levels, and ion and organic chemical data of some surface-water sampling sites and ground-water wells was performed. Instantaneous discharge measurements were compared at sites along First Creek and Uvalda Interceptor to determine whether the streams were receiving ground water discharge or recharging to ground water. Plate 3.4-1 shows the location of the wells and surface-water sampling sites that were used in this study. Table 3.4-1 lists the wells that were used in this study.

Lake and stream water levels were obtained either on a weekly or continuous basis. Instantaneous discharge measurements were obtained in September 1989. Well water level data was collected in October 1988 and February, March, April, June and September of 1989. Ion data and organic data were obtained from surface-water and ground-water sampling in 1989. The four areas that are addressed in this report are First Creek, South Plants Lakes, Havana Pond and Uvalda Interceptor. Hydrographs for Havana Pond, Upper Derby Lake, Lower Derby Lake, Ladora Lake and Lake Mary areas are presented in Figures 4.4-1 to 4.4-5. Ion Stiff diagrams are presented in Figures 4.4-6 and 4.4-7.

4.4.1 Surface-Water and Ground-Water Hydrographs

The hydrograph of Havana Pond and nearby wells completed in the alluvium (11002 and 11007) suggests an interaction between the pond and ground water (Figure 4.4-1). The water levels in the wells are lower than those of the pond, suggesting that the pond is recharging the ground water. A lack of wells on the east and south sides of the pond precludes a determination of water movement on those sides of the pond.

The water levels that were obtained from Upper Derby Lake and adjacent alluvial wells (01001, 01069, 01070 and 01073) indicate interaction between the lake and ground water (Figure 4.4-2). Water levels that were obtained from wells on the eastern (01069) and southeastern (01001) sides of the lake were similar to those measured at the lake. On the western side of the lake, water levels in wells 01070 and 01073 were lower than the levels of the lake and other wells, which indicates that the lake recharges ground water to the west-northwest.

The hydrograph of Lower Derby Lake and nearby wells (01024, 01028, 01049, 01070, 01073, 01074, 01075 and 01076) also indicates a correlation between the lake and water table (Figure 4.4-3). Two of these wells (01028 and 01076) are screened in the Denver Formation and the remainder are completed in the alluvium. Water levels in both wells were generally slightly lower than the lake levels and appeared to mimic changes in the lake level. Water levels that were obtained from the wells on the eastern side of the lake (01070 and 01073) were higher than the lake levels and the ground-water levels measured on the southern and northern sides of the lake. These data indicate that ground water discharges to the lake from the east, and the lake recharges the ground water to the west. Water migrates from a higher elevation to a lower elevation; therefore, the water levels suggest this movement from east to west.

The water levels of Ladora Lake and nearby wells (02001, 02026, 02034, 02050, 02052, 02055, 02059 and 02060) show a relationship between surface water and ground water (Figure 4.4-4). All wells are screened in the alluvium except Well 02060 which is screened in the Denver Formation. Water levels in this well correlated with lake levels but were higher than the lake levels and levels in the other wells, including adjacent Well 02059. The water level of Ladora Lake was higher than the wells located on its west side and lower than those along its east side. This suggests ground water discharges to the lake from the east and recharges from the lake to the ground water towards the west.

The hydrograph of Lake Mary and adjacent alluvial wells (02008, 02050 and 02056) indicates ground-water and surface-water interaction (Figure 4.4-5). In relationship to Lake Mary water levels, ground-water levels were higher southeast of the lake (02050) and lower northwest of the lake (02008). These data suggest that ground water discharges to the lake from the southeast, and the lake recharges the ground water to the northwest.

4.4.2 Surface-Water and Ground-Water Ion Data

Major ion chemistry data in the form of Stiff diagrams (described below) for proximal surface- and ground-water sampling locations are presented in this section. Concentrations of major ions analyzed during the spring surface-water sampling event were compared with concentrations of major ions analyzed in ground water during the spring FY89 ground-water sampling event. These data will be assessed in Section 5.0 with respect to surface-water and ground-water interactions.

A Stiff diagram is constructed of three parallel horizontal axes extending on each side of a vertical zero axis. Concentrations, in milliequivalents per liter (meq/1), of cations and anions are plotted to the left and right of the zero axis, respectively. The resulting points are connected to give an irregular polygonal shape or pattern that is used as a relatively distinctive method of illustrating differences and similarities in water compositions. The shape of the polygon provides an indication of the characteristics of natural waters. Natural waters are most often characterized by the concentration of dissolved major inorganic constituents.

Stiff diagrams constructed for samples from eight surface-water and three ground-water sampling locations within the First Creek drainage are presented in Figure 4.4-6. The farthest upstream location is presented at the top of the figure, and the farthest downstream location is presented at the bottom. Surface water within First Creek is characterized as calcium carbonate from the southern RMA boundary (South First Creek Boundary; SW08001) to the marsh area in central Section 31 (First Creek Toxic Yard B; SW31002). Downstream from the marsh area, surface water and alluvial ground water are characterized as sodium carbonate, as shown in Figure 4.4-6 by the stiff diagrams constructed for samples from Well 31016 and SW31001 (First Creek Toxic Yard A). Downstream of SW24002 (North First Creek), surface water and alluvial ground water are characterized as sodium sulfate. Ground-water samples from Well 24188, which is north of SW24002 and east of First Creek, contained extremely high concentrations of sulfate and sodium. The surface waters in the vicinity of Well 24188 are changing from sodium carbonate (upstream) to sodium sulfate (downstream), with samples from Well 24188 providing the first indication of sodium sulfate water along the reach of First Creek. Off-post north of RMA, surface water and alluvial ground water (SW37001 and 37343) are characterized as sodium sulfate.

Stiff diagrams constructed for samples from surface-water and ground-water locations in the South Plants Lakes area are presented in Figure 4.4-7. Surface water in Ladora Lake and Lake Mary is characterized as sodium carbonate and is characterized as sodium/calcium carbonate in Upper Derby Lake and Lower Derby Lake. Upstream of Ladora Lake and Lake Mary, alluvial ground water (Well 02034) and water from the Denver Formation (Well 02060) are also characterized as sodium carbonate. However, in alluvial Well 02059, also upstream of these lakes and downstream of Ladora Lake, alluvial ground water (Wells 02055 and 02056) is characterized as calcium carbonate.

Ground water exhibits a variety of characteristics in the vicinity of Upper Derby Lake and Lower Derby Lake. Ground water sampled from the Denver Formation in Well 01047, which may be upstream of Lower Derby Lake, is characterized as sodium sulfate. Ground water sampled from Well 01073, which appears to be downstream of Upper Derby Lake and upstream of Lower Derby Lake, is characterized as sodium carbonate. Ground water sampled from Well 01074, which is south of Lower Derby Lake, is similar to Upper Derby Lake (sodium/calcium carbonate). Ground water sampled from Well 02059, which is west and downstream of Lower Derby Lake, is characterized as calcium carbonate. In the same location, Well 02060 is screened in the Denver Formation and is characterized as sodium carbonate.

4.4.3 Surface-Water and Ground-Water Organic Data

A comparison of the occurrences of organic contaminants in surface water and ground water at proximal surface- and ground-water sampling locations is discussed in this section. Data from the spring surface-water sampling event were compared with spring FY89 CMP ground-water sampling results. The organic compound detections at the locations listed above are tabulated in Table 4.4-1.

The comparison indicated that within the First Creek drainage, there was no similarity between organic compounds detected in samples from on-post surface- and ground-water locations. A sample from Well 31016 contained chloroform and chlorobenzene; however, samples from adjacent surface-water locations SW31001 and SW31002 (First Creek Toxic Yard A and B, respectively) did not contain organic compounds. A sample from Well 24188 contained DIMP, but samples from an adjacent surface-water location SW24002 (North First Creek) contained Vapona. A sample from off-post Well 37343 contained six of the organic compounds detected in a sample from SW37001 (First Creek Off-Post). The concentrations of organic compounds were higher in the ground-water sample, with the exception of DCPD.

Comparison of the analytical results for surface- and ground-water samples from the South Plants Lakes area indicated an overall difference in chemical constituents. A sample from Well 01047, which is upgradient of Lower Derby Lake, contained xylenes, chloroform and DIMP. However, organic compounds were not detected in a sample from Lower Derby Lake (SW01005). Endrin was

Table 4.4-1 Comparison of Surface-Water and Ground-Water Organic Compound Detections for Spring FY89

Surface-Water Site			Ground-Water Site		
Sampling Location	Compound	Concentration (µg/l)	Sampling Location	Compound	Concentration (µg/l)
		First Creek Drainage Basin			
SW31001	ND		31016	CHCL3	0.628
SW31002	ND			CHC6H5	3.05
SW24002	Vapona	0.660	24188	DIMP	4.36
SW24004	ND				
SW37001	Chlordane	0.268	37343	Chlordane	0.612
	DCPD	21.1		DCPD	10.5
	DIMP	88.0		DIMP	140
	Dieldrin	0.0577		Dieldrin	0.112
	Endrin	0.0643		Endrin	0.179
	PPDDT	0.0571		PPDDT	0.263
	Atrazine	9.59		CHC6H5	1.03
		Irondale Gulch Drainage Basin, South Plants Lakes Area			
SW01004	Endrin	0.0533	01073	ND	
SW01005	ND		01074	ND	
			02059	ND	
			02060	ND	
			01047	Xylenes (o,p)	1.91
				CHCL3	3.64
				DIMP	4.34
SW02003	ND		02034	11DCLE	2.65
SW02004	Isodrin	0.0972			
				Aldrin	0.683
				Benzene	6.17
				CHCL3	8.37
				DIMP	1.29
				Dieldrin	0.205
				Endrin	0.154
				Isodrin	0.361
				PPDDT	0.385
				Parathion	1.63
				Supona	1.97
				TCLEE	1.54
				TRCLE	3.02
			02055	ND	
			02056	ND	

µg/l = micrograms per liter
ND = no detections of organic compounds

detected at a concentration near the CRL in a sample from Upper Derby Lake (SW01004). Samples from Wells 01073, 01074, 02059 and 02060 which are downgradient of the Upper Derby Lake and Lower Derby Lake, contained no chemicals. A sample from Well 02034, which is upgradient of Ladora Lake and Lake Mary, contained organochlorine pesticides, volatile organohalogens, organophosphorus compounds and volatile aromatics. However, only isodrin was detected in a sample from Ladora Lake (SW02003). Samples from Wells 02055 and 02056, which are downgradient of Ladora Lake, did not contain organic compounds.

4.4.4 Gain-Loss

Instantaneous discharge measurements were taken during the fall (September 29, 1989) to determine gain-loss relationships along First Creek and Uvalda Interceptor to be used in determining the degree of ground-water/surface water interaction. A total of three measurements were taken at selected sites on each drainage. Sites SW08001, SW08003 and SW08004 were chosen on First Creek, and sites SW12005, SW12008 and SW12009 were selected on Uvalda Interceptor (Plate 3.4-1).

Based upon these discharge measurements, First Creek is a losing (influent) stream (Appendix A-2.3, Table A-2.3-1) along this reach of the creek. Discharge decreased from 0.14 cfs at SW08001 to 0.06 cfs at SW08003, and to 0.04 cfs at SW08004 in the downstream direction. Depending on season, however, First Creek also behaves as a gaining (effluent) stream. Generally, First Creek is an influent stream from July through October, and is an effluent stream from November through June.

South Uvalda station exhibits flow year-round but discharge decreased from 0.17 cfs at SW12005 to 0.11 cfs at SW12008 and to 0.10 cfs at SW12009 in the downstream direction, based upon discharge measurements taken on September 29, 1989 (Appendix A-2.3, Table A-2.3-1). Flow at the South Uvalda monitoring station appears to be attributed to base flow, however, downstream of the station, flow gradually approaches zero near Sixth Avenue due to backwatering caused by the diversion structure. Flow downstream of the South Uvalda monitoring station appears to be controlled by temporal variations. Generally, flow is considered to be effluent but can shift to influent during dry periods.

4.5 Quality Assurance/Quality Control Results of Water Quality Data

Quality Assurance (QA) is defined as the program for assuring and documenting the reliability of monitoring and measurement data. QA as it relates to the analytical results generated by the CMP Surface-Water Program assesses the data in terms of its precision, accuracy and comparability.

Quality Control (QC) is the routine application of procedures for obtaining prescribed standards of performance in the monitoring and measurement process. QC procedures are established during the analytical certification and include delineation of control limits for matrix spike and surrogate recoveries as well as the evaluation of method blank data for each lot of samples. The laboratory quality control data is reported in weekly quality assurance Status Reports which include accuracy and precision control chart reviews. Deviations from established quality control criteria are evaluated by the laboratory to determine the appropriate corrective action to be implemented by the laboratory Quality Assurance Coordinator. Quality Control data are evaluated as unacceptable or acceptable by the Project Quality Assurance Coordinator. The Project Quality Assurance Coordinator then recommends the appropriate action to the PM RMA QA Manager for approval and addition to the database. Any data rejected by the PM RMA QA Manager was loaded into a rejected database file for informational purposes only. Table 4.5-1 lists the samples by analysis that were rejected during Water Year 1989 by Quality Assurance Management.

4.5.1 Organic and Inorganic Compounds Quality Assurance and Quality Control Results

Field quality control data is generated by collecting field, trip and rinse blanks at a rate of 5 percent each of the total number of samples and duplicate samples at a rate of 10 percent of the total. Review of the field QC data is the principal focus of this section of the surface-water report. QC data that was evaluated include results from method, field, trip, and rinse blanks, duplicate samples, and confirmatory GC/MS analysis.

4.5.1.1 Blank Results. Method blanks contained concentrations of inorganic and organic target analytes. One method blank contained chromium and copper concentrations of 16.8 and 11 μg/l, respectively. One method blank contained copper at 2.9 μg/l and one organic method blank detected xylene at 4.0 μg/l. No xylene was reported in the sample results.

One rinse blank, two trip blanks and two field blanks were collected to evaluate the effect of contamination during sampling and transport of the field samples and the effectiveness of the sampling equipment decontamination procedures. One trip blank indicated DMMP at 1.0 μg/l. Review of the chromatograph and the lot report indicated this result could be background or carry over contamination from the previous laboratory sample. The field sample result at SW01001 associated with this trip blank also indicated DMMP at 1.0 μg/l and could be considered suspect.

Nitrate was detected in two field blanks and one trip blank. For SW01001 the nitrate found in the trip blank was significantly below the concentration found in field blanks at SW11002 and SW36001, the nitrate results appear to be associated with the laboratory water. For SW02003,

Table 4.5-1 Surface-Water Rejected Data

Site	Date	Rejection	Lot	Analysis
SW01001B	89117	reject CPMSO at or above the CRL	GFA	Sulf. Pest.
		reject all Aromatic results at or above the CRL	GFT	Aromatics
		reject vapona	GFR	N/P Pest.
SW01002	89138	reject all Data	GLG	N/P Pest.
		reject all Chlorine Data at or above the CRL	GLH	Chlorine Pest.
		reject DMDS	GLJ	Sulf. Pest.
SW01002B	89138	reject all Halogens at or above the CRL	GLW	Halogens
		reject all Chlorine Pest. Dat at or above the CRL	GLS	Chlorine Pest.
SW01004	89109	reject all Halogens at or above the CRL	GCP	Halogens
		reject DMDS at or above the CRL	GCZ	Sulf. Pest.
		reject all DBCP results at or above the CRL	GDA	DBCP
SW01005	89108	reject all Halogens at or above the CRL	GCP	Halogens
		reject DMDS at or above the CRL	GCZ	Sulf. Pest.
		reject all DBCP results at or above the CRL	GDA	DBCP
SW01005D	89108	reject all Halogens at or above the CRL	GCP	Halogens
		reject DMDS at or above the CRL	GCZ	Sulf. Pest.
		reject all DBCP results at or above the CRL	GDA	DBCP
SW02002	89135	reject all CL6CP data	GKK	Chlorine Pest.
		reject MIBK and BCHPD at or above the CRL	GKQ	Hydrocarbons
SW02003	89108	reject all Halogens at or above the CRL	GCP	Halogens
		reject DMDS at or above the CRL	GCZ	Sulf. Pest.
		reject all DBCP results at or above the CRL	GDA	DBCP
SW02004	89109	reject all Halogens at or above the CRL	GCP	Halogens
		reject DMDS at or above the CRL	GCZ	Sulf. Pest.
		reject all DBCP results at or above the CRL	GDA	DBCP
SW02006	89117	reject CL6CP at or above the CRL	GFG	Chlorine Pest.
SW02006B	89117	reject all Aromatic results at or above the CRL	GFT	Aromatics
		reject vapona	GFR	N/P Pest.
SW04001ST	89135	reject all CL6CP data	GKK	Chlorine Pest.
		reject MIBK and BCHPD at or above the CRL	GKQ	Hydrocarbons
SW07001	89117	reject CL6CP at or above the CRL	GFG	Chlorine Pest.
SW07001B	89117	reject CPMSO at or above the CRL	GFA	Sulf. Pest.
		reject vapona	GFR	N/P Pest.
		reject all Aromatic results at or above the CRL	GFT	Aromatics

Table 4.5-1 Surface-Water Rejected Data (continued)

Site	Date	Rejection	Lot	Analysis
SW08001	89115	reject all Halogens at or above the CRL	GCP	Halogens
		reject Parathion only	GEJ	N/P Pest.
		reject DIMP & DMMP at or above the CRL	GEH	Phosphonates
SW08001B	89115	reject Chlorine Pesticides	GEB	Chlorine Pest.
		reject vapona only	GEA	N/P Pest.
		reject CPMSO at or above the CRL	GEC	Sulf. Pest.
		reject all Aromatics at or above the CRL	GDW	Aromatics
SW08003	89115	reject all Halogens at or above the CRL	GCP	Halogens
		reject Parathion below the LCL	GEJ	N/P Pest.
		reject DIMP & DMMP at or above the CRL	GEH	Phosphonates
SW08003B	89115	reject Chlorine Pesticides	GEB	Chlorine Pest.
		reject vapona only	GEA	N/P Pest.
		reject CPMSO at or above the CRL	GEC	Sulf. Pest.
		reject all Aromatics at or above the CRL	GDW	Aromatics
SW08003ST	89134	reject CPMSO at or above the CRL	GJY	Sulf. Pest.
		reject CL6CP at or above the CRL	GJV	Chlorine Pest.
		reject MIBK at or above the CRL	GKC	Hydrocarbons
SW11001	89116	reject all Halogens at or above the CRL	GCP	Halogens
		reject CL6CP at or above the CRL	GFG	Chlorine Pest.
SW11001D	89116	reject all Halogens at or above the CRL	GCP	Halogens
		reject CL6CP at or above the CRL	GFG	Chlorine Pest.
SW11001B	89116	reject CPMSO at or above the CRL	GFA	Sulf. Pest.
		reject vapona	GFR	N/P Pest.
		reject all Aromatic results at or above the CRL	GFT	Aromatics
SW11001BD	89116	reject CPMSO at or above the CRL	GFA	Sulf. Pest.
		reject vapona	GFR	N/P Pest.
		reject all Aromatic results at or above the CRL	GFT	Aromatics
SW11002	89116	reject all Halogens at or above the CRL	GCP	Halogens
		reject CL6CP at or above the CRL	GFG	Chlorine Pest.
SW11002FB	89116	reject all Halogens at or above the CRL	GCP	Halogens
		reject CL6CP at or above the CRL	GFG	Chlorine Pest.
SW11002B	89116	reject CPMSO at or above the CRL	GFA	Sulf. Pest.
		reject vapona	GFR	N/P Pest.
		reject all Aromatic results at or above the CRL	GFT	Aromatics

Table 4.5-1 Surface-Water Rejected Data (continued)

Site	Date	Rejection	Lot	Analysis
SW11003	89115	reject all Halogens at or above the CRL	GCP	Halogens
		reject Parathion below the LCL	GEJ	N/P Pest.
		reject DIMP & DMMP at or above the CRL	GEH	Phosphonates
SW12001	89110	reject all Halogens at or above the CRL	GCP	Halogens
		reject DMDS at or above the CRL	GCZ	Sulf. Pest.
		reject all DBCP results at or above the CRL	GDA	DBCP
SW12002	89135	reject all CL6CP data	GKK	Chlorine Pest.
		reject MIBK and BCHPD at or above the CRL	GKQ	Hydrocarbons
SW12003B	89110	reject all Chlorine Pesticides	GDD	Chlorine Pest.
		reject vapona	GDF	N/P Pest.
		reject CPMSO above the CRL	GDC	Sulf. Pest.
SW12004	89109	reject all Halogens at or above the CRL	GCP	Halogens
		reject DMDS at or above the CRL	GCZ	Sulf. Pest.
		reject all DBCP results at or above the CRL	GDA	DBCP
SW12004B	89107	reject all Chlorine Pesticides	GDD	Chlorine Pest.
		reject vapona	GDF	N/P Pest.
		reject CPMSO above the CRL	GDC	Sulf. Pest.
SW12005	89107	reject all Halogens at or above the CRL	GCP	Halogens
		reject DMDS at or above the CRL	GCZ	Sulf. Pest.
SW12005B	89107	reject all Chlorine Pesticides	GDD	Chlorine Pest.
		reject vapona	GDF	N/P Pest.
		reject CPMSO above the CRL	GDC	Sulf. Pest.
SW24001	89138	reject all Data	GLG	N/P Pest.
		reject all Chlorine Pest. Data at or above the CRL	GLH	Chlorine Pest.
		reject DMDS	GLJ	Sulf. Pest.
SW24001D	89138	reject all Data	GLG	N/P Pest.
		reject all Chlorine Pest. Data at or above the CRL	GLH	Chlorine Pest.
		reject DMDS	GLJ	Sulf. Pest.
SW24002	89111	reject all Halogens at or above the CRL	GCP	Halogens
		reject Parathion only	GEJ	N/P Pest.
		reject DIMP & DMMP at or above the CRL	GEH	Phosphonates
SW24002B	89111	reject Chlorine Pesticides	GEB	Chlorine Pest.
		reject vapona only	GEA	N/P Pest.
		reject CPMSO at or above the CRL	GEC	Sulf. Pest.
		reject all Aromatics at or above the CRL	GDW	Aromatics

Table 4.5-1 Surface-Water Rejected Data (continued)

Site	Date	Rejection	Lot	Analysis
SW24002BD	89111	reject Chlorine Pesticides	GEB	Chlorine Pest.
		reject vapona only	GEA	N/P Pest.
		reject CPMSO at or above the CRL	GEC	Sulf. Pest.
		reject all Aromatics at or above the CRL	GDW	Aromatics
SW24002ST	89135	reject CPMSO at or above the CRL	GJY	Sulf. Pest.
		reject CL6CP at or above the CRL	GJV	Chlorine Pest.
		reject MIBK at or above the CRL	GKC	Hydrocarbons
SW24003	89111	reject all Halogens at or above the CRL	GCP	Halogens
		reject Parathion only	GEJ	N/P Pest.
		reject DIMP & DMMP at or above the CRL	GEH	Phosphonates
SW24004	89114	reject all Halogens at or above the CRL	GCP	Halogens
		reject Parathion only	GEJ	N/P Pest.
		reject DIMP & DMMP at or above the CRL	GEH	Phosphonates
SW30002	89114	reject all Halogens at or above the CRL	GCP	Halogens
		reject Parathion only	GEJ	N/P Pest.
		reject DIMP & DMMP at or above the CRL	GEH	Phosphonates
SW30002B	89114	reject Chlorine Pesticides	GEB	Chlorine Pest.
		reject vapona only	GEA	N/P Pest.
		reject CPMSO at or above the CRL	GEC	Sulf. Pest.
		reject all Aromatics at or above the CRL	GDW	Aromatics
SW31001	89114	reject all Halogens at or above the CRL	GCP	Halogens
		reject Parathion only	GEJ	N/P Pest.
		reject DIMP & DMMP at or above the CRL	GEH	Phosphonates
SW31001B	89114	reject Chlorine Pesticides	GEB	Chlorine Pest.
		reject vapona only	GEA	N/P Pest.
		reject CPMSO at or above the CRL	GEC	Sulf. Pest.
		reject all Aromatics at or above the CRL	GDW	Aromatics
SW31002	89115	reject all Halogens at or above the CRL	GCP	Halogens
		reject Parathion only	GEJ	N/P Pest.
		reject DIMP & DMMP at or above the CRL	GEH	Phosphonates
SW31002B	89114	reject Chlorine Pesticides	GEB	Chlorine Pest.
		reject vapona only	GEA	N/P Pest.
		reject CPMSO at or above the CRL	GEC	Sulf. Pest.
		reject all Aromatics at or above the CRL	GDW	Aromatics
SW36001	88273	reject CL6CP at or above the CRL	GFG	Chlorine Pest.

Table 4.5-1 Surface-Water Rejected Data (continued)

Site	Date	Rejection	Lot	Analysis
SW36001B	89118	reject vapona	GFR	N/P Pest.
		reject all Aromatic results at or above the CRL	GFT	Aromatics
SW37001	89110	reject all Halogens at or above the CRL	GCP	Halogens
		reject DMDS at or above the CRL	GCZ	Sulf. Pest.
		reject all DBCP result at or above CRL	GDA	DBCP
SW37001B	89110	reject Chlorine Pesticides	GDD	Chlorine Pest.
		reject vapona	GDF	N/P Pest.
		reject CPMSO above the CRL	GDC	Sulf. Pest.

CRL = certified reporting limit
B = bottom sediment sample
D = duplicate sample
ST = storm sample
FB = field blank sample

nitrate and zinc were found at concentrations of 94 $\mu g/l$ and 63 $\mu g/l$ in rinse blanks. These results are above the associated field sample and may indicate insufficient decontamination of sampling or laboratory equipment.

4.5.1.2 Duplicate Results. Duplicate samples were collected and analyzed to evaluate sampling and analytical precision. Table 4.5-2 presents the results of the sample and duplicate analyses. Of the duplicate samples, two organic results for the sample/duplicate set were at concentrations above the certified reporting limit (CRL). Historically, the CMP has employed an order of magnitude agreement for duplicate results since guidance is currently unavailable under the chemical Quality Assurance Plan for the Rocky Mountain Arsenal. Sample/duplicate results for both hits agree within an order of magnitude, although the duplicate results for hexachlorocyclopentadiene was more than twice the sample result.

The inorganic duplicate/sample results were evaluated by calculating the relative percent difference (RPD) for those results greater than five times the CRL. Control limits of ±20 percent of the RPD have been recommended by EPA. One result for nitrate-nitrite exceeded the recommended RPD value.

For values less than five times the CRL, sample/duplicate results, control limits of ± the CRL are used for the assessment. One of the sample/duplicate sets had zinc results at less than five times the CRL. These results were within the one CRL criteria.

4.5.1.3 Gas Chromatography/Mass Spectrometry (GC/MS Results). GC/MS samples were collected and analyzed to provide confirmation of GC results and to provide tentatively identified compound and unknown compound data for identification of potential additions to the target analyte list. Twenty-two GC/MS samples were collected and analyzed. Additional GC/MS analysis were performed on three samples for volatile compounds. Fourteen additional GC/MS semi-volatile analytical results are also available as a result of the analytical request for Acid Extractables. Seventy-three positive values were detected in samples where both GC and GC/MS analysis were performed. A total of sixteen samples were confirmed by GC/MS, 10 were not confirmed and 47 were unconfirmable because the GC analytical results were below the CRL for the GC/MS analysis. Table 4.5-3 presents the results of the GC/MS confirmations.

Table 4.5-2 Surface Water Duplicate Percent and Relative Percent Difference

Analyte	Sample ($\mu g/l$)	Duplicate ($\mu g/l$)	Difference ($\mu g/l$)	Percent Agreement	Relative Percent Difference	CRL ($\mu g/l$)
Arsenic	29.00	25.80	3.2	88.97	11.68	2.35
Calcium	4.94×10^{4}	4.77×10^{4}	1.70×10^{3}	96.56	3.50	500.00
	1.67×10^{4}	1.53×10^{4}	1.40×10^{3}	91.62	8.75	500.00
	3.67×10^{4}	3.84×10^{4}	-1.70×10^{3}	104.63	-4.53	500.00
Chloride	3.30×10^{4}	3.30×10^{4}	0.00	100.00	0.00	720.00
	5.59×10^{4}	5.78×10^{3}	-2.80×10^{2}	103.40	-3.34	720.00
	4.70×10^{4}	4.60×10^{4}	1.00×10^{3}	97.87	2.15	720.00
Fluoride	1.00×10^{3}	1.09×10^{3}	-9.00×10^{1}	109.00	-8.61	482.00
	1.16×10^{3}	1.10×10^{3}	6.00×10^{1}	94.83	5.31	482.00
Magnesium	1.42×10^{4}	1.37×10^{4}	5.00×10^{2}	96.48	3.58	500.00
	2.60×10^{3}	2.65×10^{3}	-5.00×10^{1}	101.93	-1.90	500.00
	1.18×10^{4}	1.24×10^{4}	-6.00×10^{2}	105.08	-4.96	500.00
Nitrite-Nitrate (nonspecific)	5.74×10^{1}	7.46×10^{1}	-1.72×10^{1}	129.97	-26.06	10.00
	2.50×10^{2}	2.50×10^{2}	0.00	100.00	0.00	10.00
	4.40×10^{3}	4.40×10^{3}	0.00	100.00	0.00	10.00
Potassium	3.89×10^{3}	3.58×10^{3}	3.10×10^{2}	92.03	8.30	250.00
	3.24×10^{3}	2.96×10^{3}	2.80×10^{2}	91.36	9.03	250.00
	4.79×10^{3}	4.78×10^{3}	6.10×10^{1}	98.75	1.26	250.00
Sulfate	6.90×10^{4}	7.00×10^{4}	1.00×10^{3}	98.59	1.42	251.00
	2.20×10^{4}	2.10×10^{4}	1.00×10^{3}	95.45	4.65	251.00
	6.90×10^{4}	6.90×10^{4}	0.00	100.00	0.00	251.00
Zinc	LT 2.20×10^{1}	2.81×10^{1}	>-6.10	--	--	22.00
	3.02×10^{1}	LT 2.20×10^{1}	<8.20	--	--	22.00
	4.54×10^{1}	3.39×10^{1}	1.15×10^{1}	74.67	--	22.00
Hexachlorocyclopentadiene	7.10×10^{-1}	1.80	-1.09	253.52	-86.85	0.048
Tetrachloroethene	1.38	1.29	0.09	93.48	6.74	1.000

LT Less Than

SWR-89-M.TBL

Table 4.5-3 Confirmation Analysis Results

Date	Well No.	Analyte	Result	Status	Method
89117	SW01001	Dimethylmethyl Phosphonate	1.03	3	AT8
89117	SW01001TB	Dimethylmethyl Phosphonate	7.76×10^{-1}	3	AT8
89138	SW01002	Aldrin	3.20	3	KK8
		Atrazine	8.52×10^{1}	2	UH11
		Chloroform	7.07	1	N8
		Hexachlorocyclopentadiene	2.21×10^{-1}	3	KK8
		Chlordane	9.90	3	KK8
		p-Chlorophenylmethylsulfoxide	7.50×10^{2}	1	AAA8
		p-Chlorophenylmethylsulfone	8.40×10^{1}	3	AAA8
		Dibromochloropropane	3.80×10^{1}	2	AV8
		Dicyclopentadiene	9.69×10^{1}	1	P85
		Dieldrin	2.00	3	KK8
		Endrin	4.70×10^{-1}	3	KK8
		Isodrin	7.40×10^{-1}	3	KK8
		Toluene	4.42	2	AV8
		Malation	1.07×10^{1}	3	UH11
		Dichlorodiphenyltrichloroethane (DDT)	1.93×10^{-1}	3	KK8
		Parathion	1.51×10^{-1}	3	UH11
		2-Chloro-1(2,4-Dichlorphenyl) Vinyldiethylphosphate	7.10	3	UH11

* Greater than UCRL reported for confirmation
1 Confirmed
2 Not Confirmed
3 Uncomfirmable

SWAR2-89.TBL

Table 4.5-3 Confirmation Analysis Results (continued)

Date	Well No.	Analyte	Result	Status	Method
89138	SW01002 (cont'd)	Tetrachloroethene	1.64	1	N8
89109	SW01004	Dieldrin	4.93×10^{-2}	3	KK8
		Endrin	5.33×10^{-2}	3	KK8
89109	SW02004	Isodrin	9.72×10^{-2}	1	KK8
89117	SW02006	Chloroform	4.33	1	N8
		Dimethylmethyl Phosphonate	2.54	3	AT8
89270	SW02006	Chloroform	3.75	2	N8
89135	SW04001ST	Dieldrin	5.51×10^{-2}	3	KK8
89117	SW07001	Aldrin	1.52×10^{-2}	3	KK8
		Hexachlorocyclopentadiene	1.75×10^{-2}	3	KK8
		Vapona	1.86	3	UH11
		Dieldrin	7.95×10^{-2}	3	UH11
		Dimethylmethyl Phosphonate	2.08	3	AT8
		Isodrin	1.32×10^{-1}	3	KK8
		Dichlorodiphenylethane (DDE)	2.52×10^{-1}	3	KK8
		Dichlorodiphenyltrichloroethane (DDT)	6.38×10^{-2}	3	KK8
89115	SW08001	Vapona	7.88×10^{-1}	3	UH11
89296	SW08003	Dieldrin	6.96×10^{-2}	3	KK8
		Endrin	7.62×10^{-2}	3	KK8
89134	SW08003ST	Dibromochloropropane	2.41×10^{-1}	3	AY8

* Greater than UCRL reported for confirmation
1 Confirmed
2 Not Confirmed
3 Uncomfirmable

SWAR2-89.TBL

Table 4.5-3 Confirmation Analysis Results (continued)

Date	Well No.	Analyte	Result	Status	Method
89116	SW11001	Hexachlorocyclopentadiene	7.10×10^{-1}	3	KK8
89116	SW11001D	Hexachlorocyclopentadiene	1.80	3	KK8
89116	SW11002	Dimethylmethyl Phosphonate	4.30×10^{-1}	3	AT8
89115	SW11003	Aldrin	5.81×10^{-2}	3	KK8
		Chlordane	1.49×10^{-1}	3	KK8
		Vapona	7.27×10^{-1}	3	UH11
		Dichlorophenyltrichlorethane (DDT)	5.52×10^{-2}	3	KK8
89110	SW12003	Endrin	5.88×10^{-2}	3	KK8
89109	SW12004	p-Chlorophenylmethyl Sulfoxide	3.59×10^{1}	2	AAA8
89270	SW24001	Dimethylmethyl Phosphonate	4.7×10^{-1}	3	AT8
89111	SW24003	Diisopropylmethyl Phosphonate	2.06	3	AT8
89114	SW30002	Vapona	6.35×10^{-1}	3	UH11
89118	SW36001	1,1,2-Trichloroethane	1.20×10^{1}	2	N8
		1,2-Dochloroethane	7.30×10^{1}	2	N8
		m-Xylene	1.80×10^{2}	1	AV8
		Aldrin	6.50	3	KK8
		Atrazine	3.70×10^{2}	1	UH11
		Benzene	3.60×10^{2}	1	AV8
		Chloroform	9.40×10^{2}	1	N8
		Hexachlorocyclopentadiene	1.00	3	KK8
		Chlordane	6.40×10^{1}	1	KK8

* Greater than UCRL reported for confirmation
1 Confirmed
2 Not Confirmed
3 Uncomfirmable

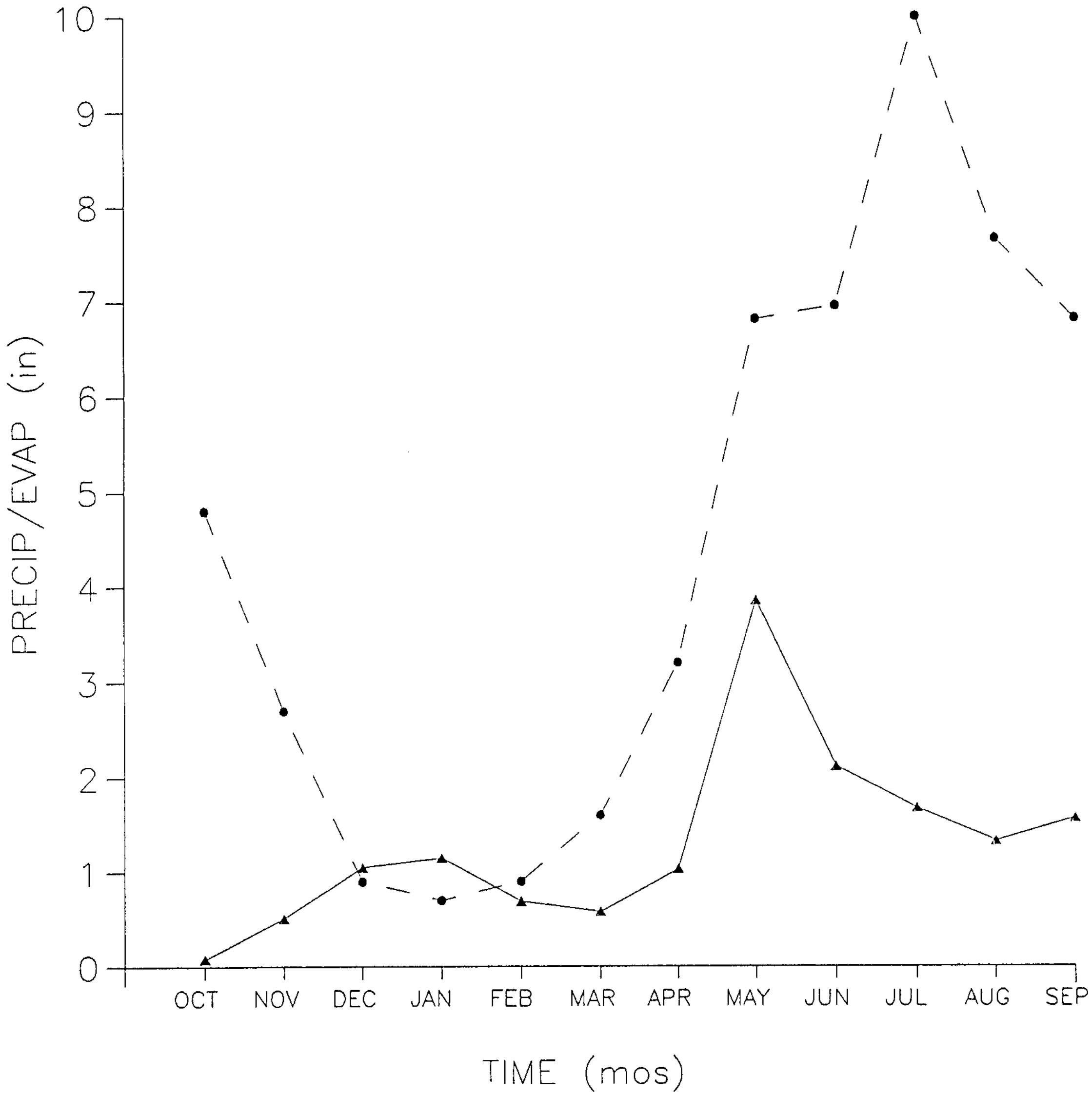
SWAR2-89.TBL

Table 4.5-3 Confirmation Analysis Results (continued)

Date	Well No.	Analyte	Result	Status	Method
89118	SW36001 (cont'd)	Chlorobenzene	7.50×10^{3}	1	N8
		p-Chlorophenylmethyl Sulfide	1.20×10^{2}	1	AAA8
		p-Chlorophenylmethyl Sulfoxide	7.37×10^{1}	2	AAA8
		p-Chlorophenylmethyl Sulfone	1.60×10^{3}	1	AAA8
		Dibromochloropropane	1.30×10^{2}	1	AY8
		Dicyclopentadiene	7.67×10^{1}	1	P8
		Vapona	5.70×10^{1}	1	UH11
		Diisopropylmethyl Phosphonate	4.13	3	AT8
		Dithiane	1.58	2	AAA8
		Dieldrin	6.50	3	KK8
		Dimethylmethyl Phosphonate	1.08×10^{1}	2	AT8
		Endrin	6.80×10^{-1}	3	KK8
		Ethylbenzene	3.10×10^{2}	1	AV8
		Isodrin	4.55×10^{-1}	3	KK8
		Toluene	1.40	1	AV8

* Greater than UCRL reported for confirmation
1 Confirmed
2 Not Confirmed
3 Uncomfirmable

SWAR2-89.TBL

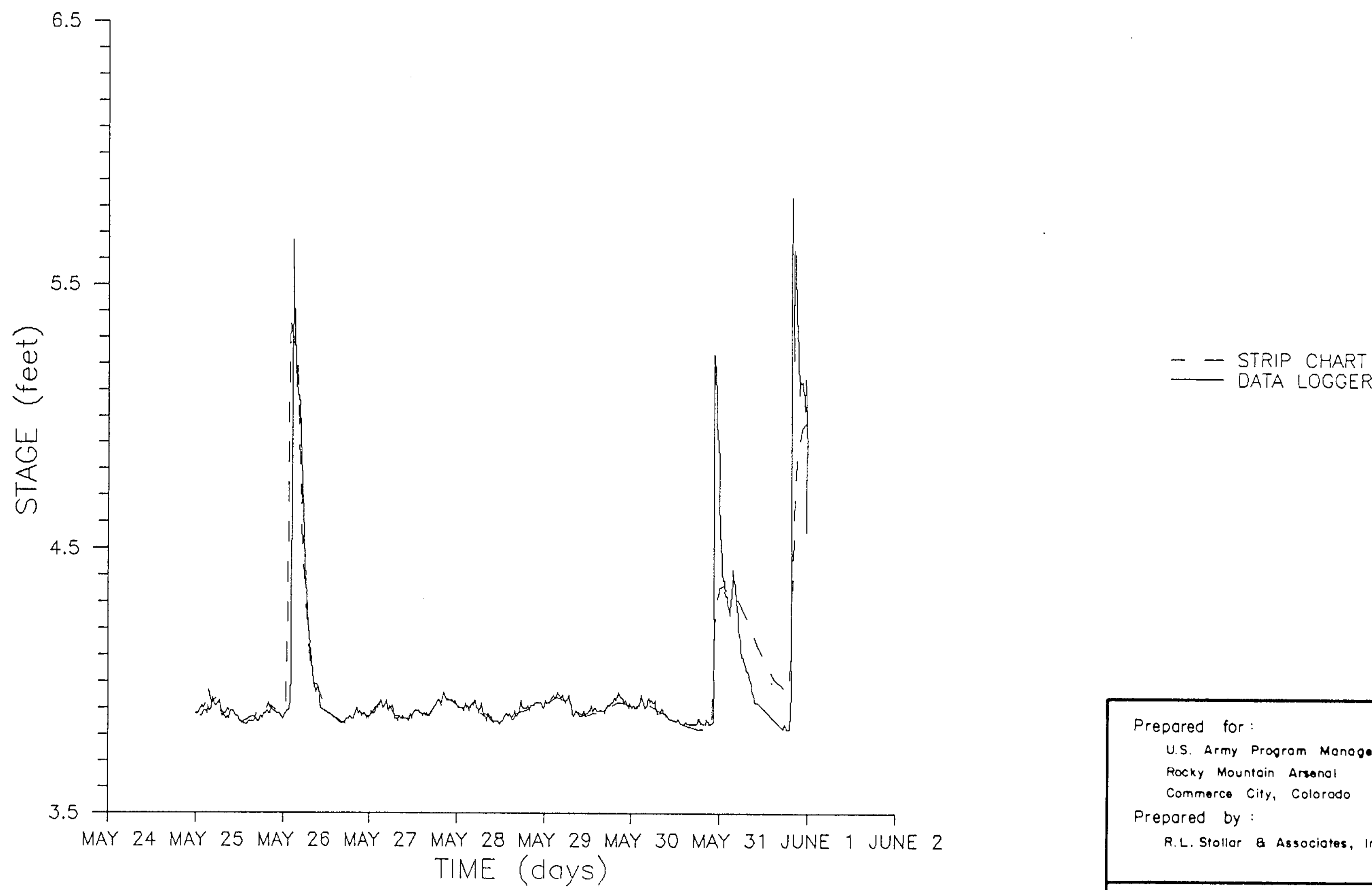


Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
R.L. Stollar & Associates, Inc.

Figure **4.1-1**

Precipitation and Evaporation Water Year 1989

CMP SW FY89



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Prepared by :
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Figure **4.1-2**

South Uvalda Comparison of Strip Chart and Data Logger Stage Data

CMP SW FY89

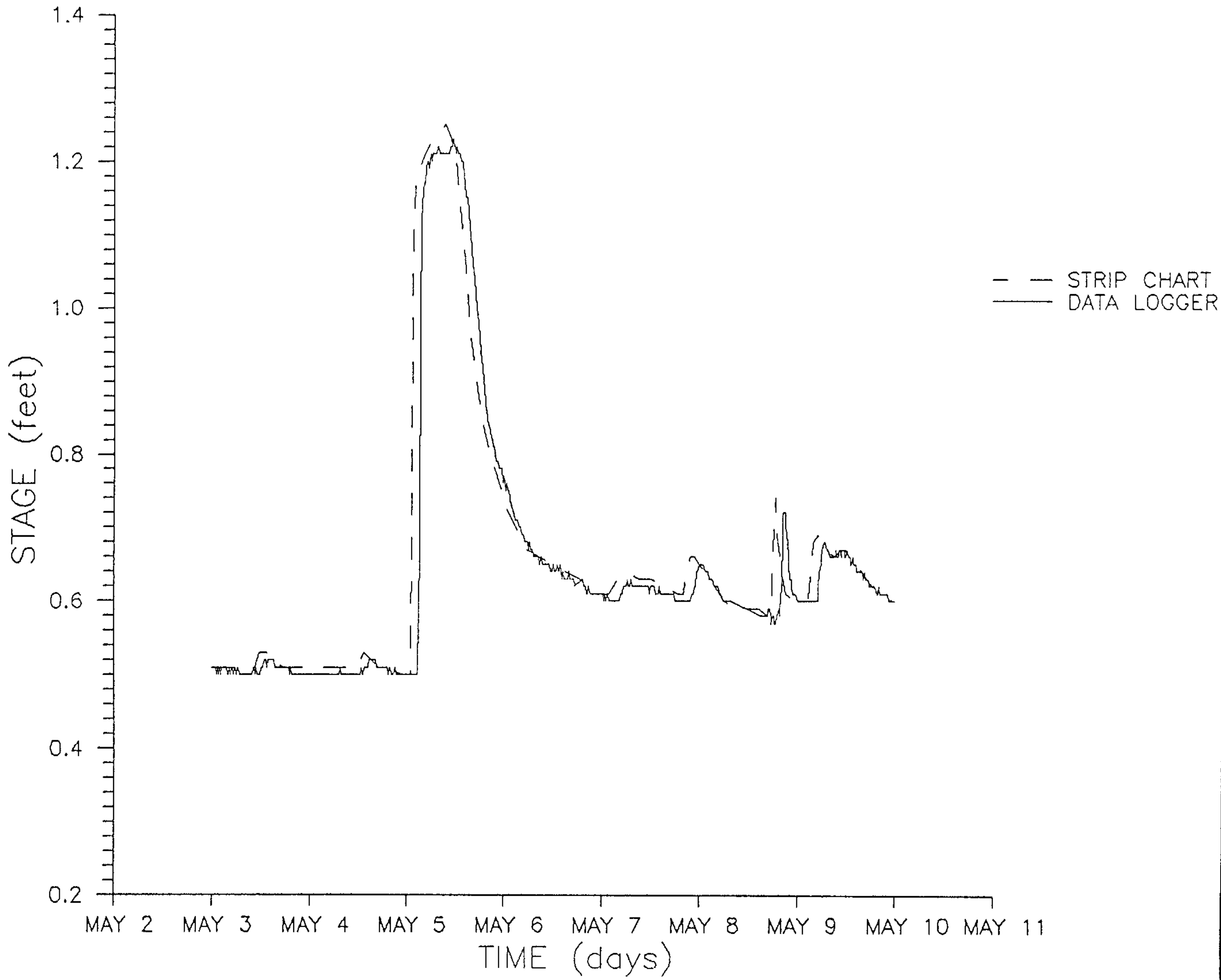

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Figure **4.1-3**

South First Creek
Comparison of Strip Chart and Data Logger Stage Data

CMP SW FY89

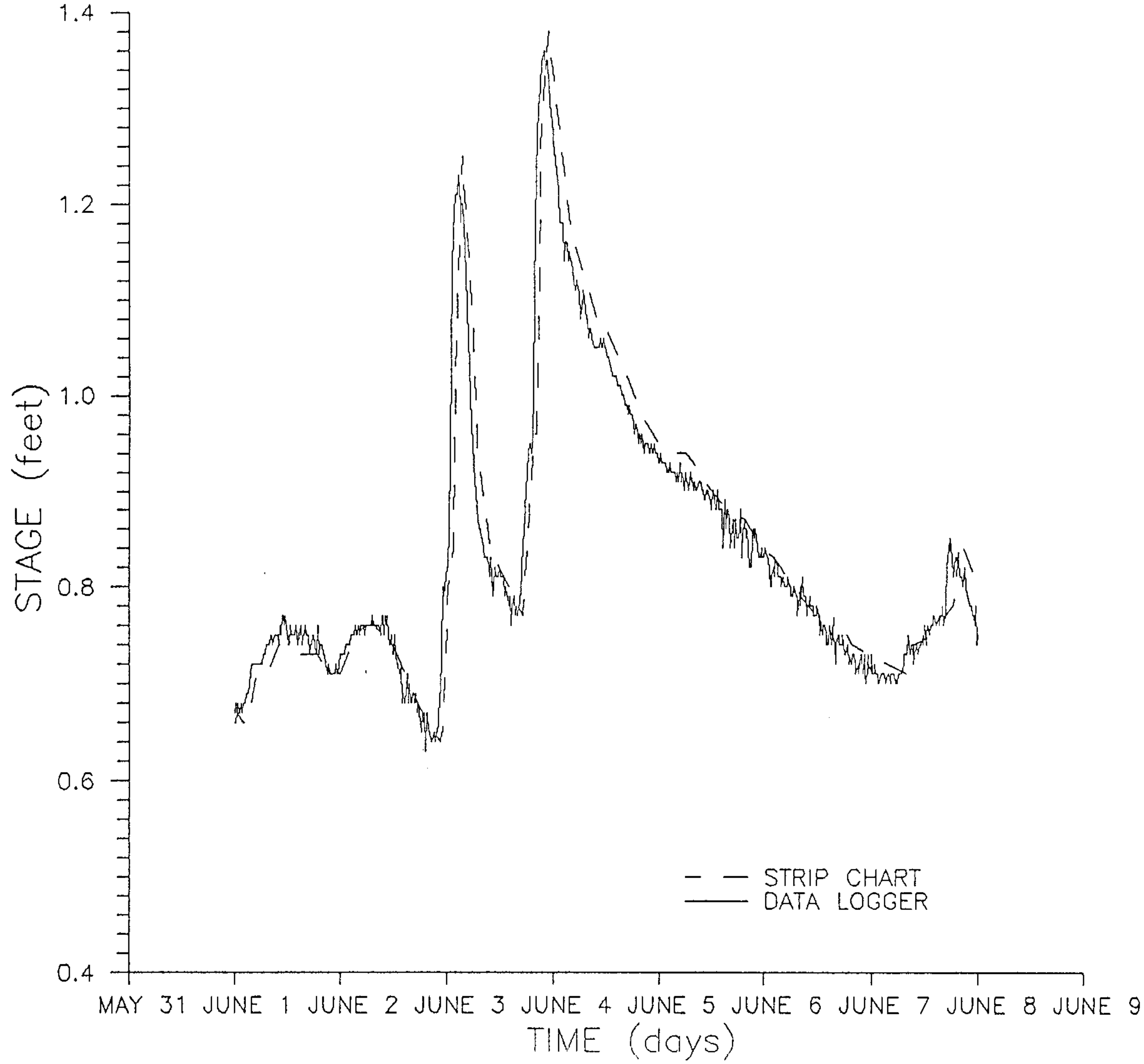

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Figure **4.1-4**
North First Creek
Comparison of Strip Chart and Data Logger Stage Data

CMP SW FY89

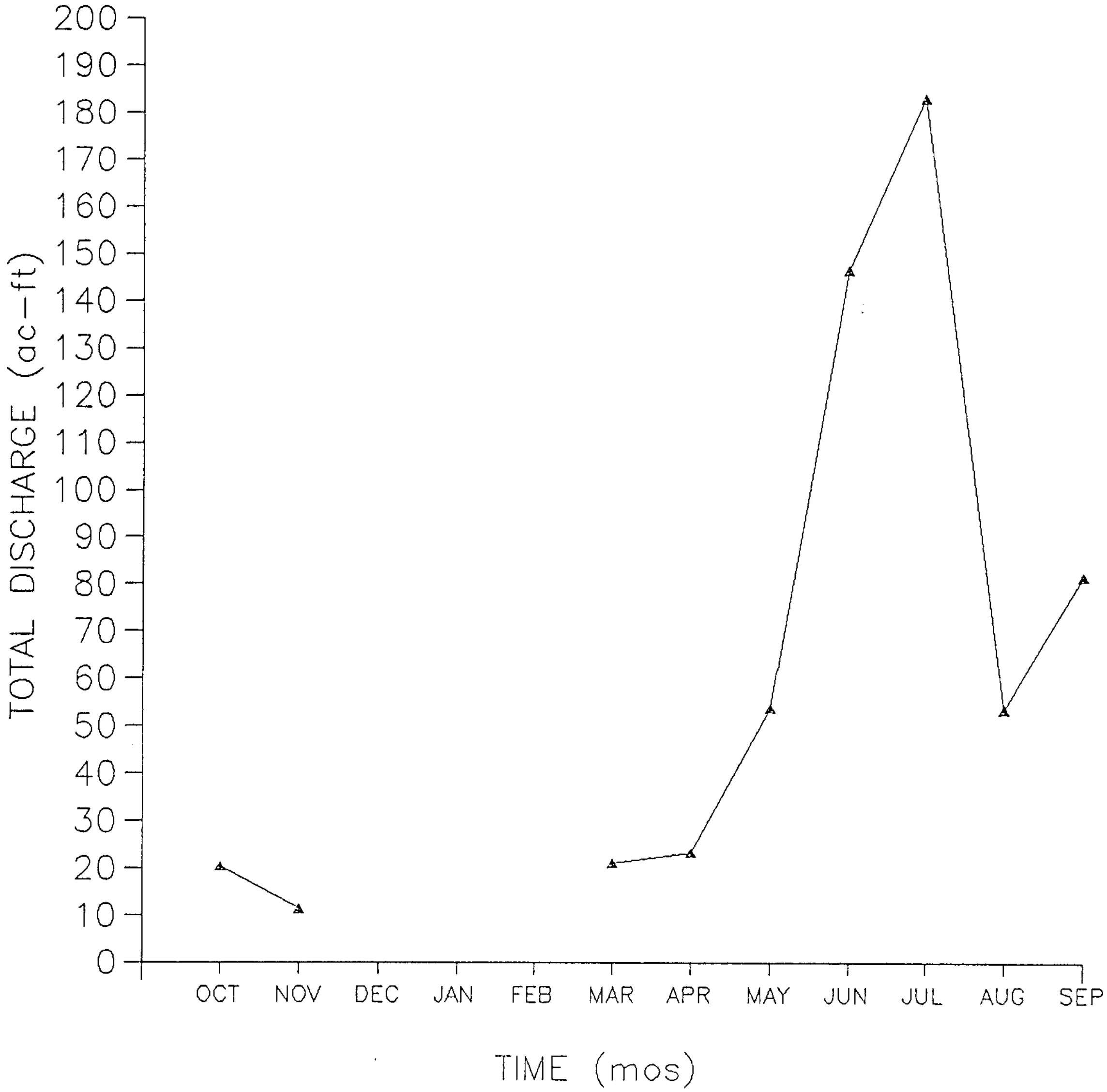

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Figure **4.1-5**

Havana Interceptor
Monthly Total Discharge
WY89

CMP SW FY89

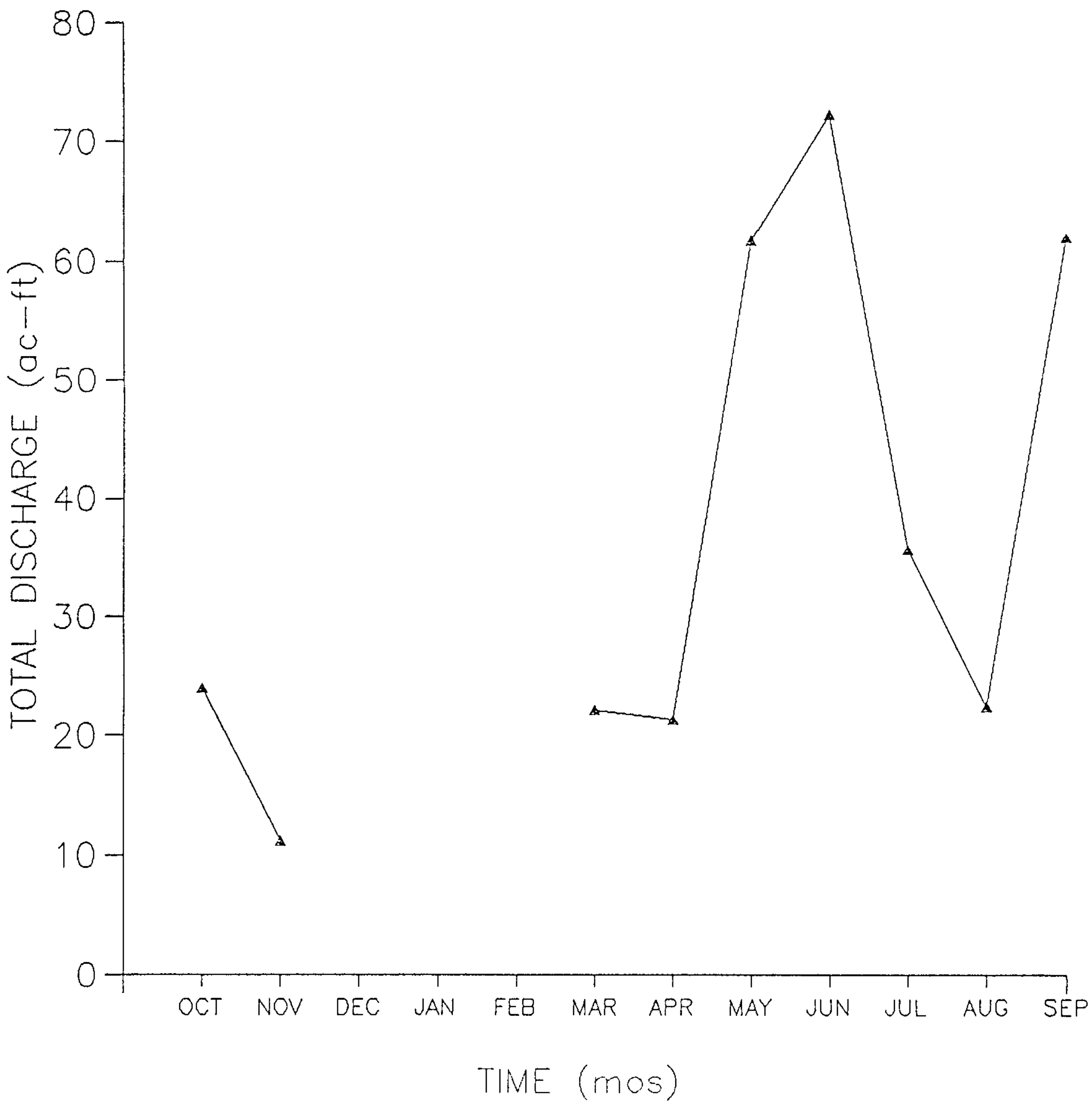

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Figure **4.1-6**

Peoria Interceptor
Monthly Total Discharge
WY89

CMP SW FY89

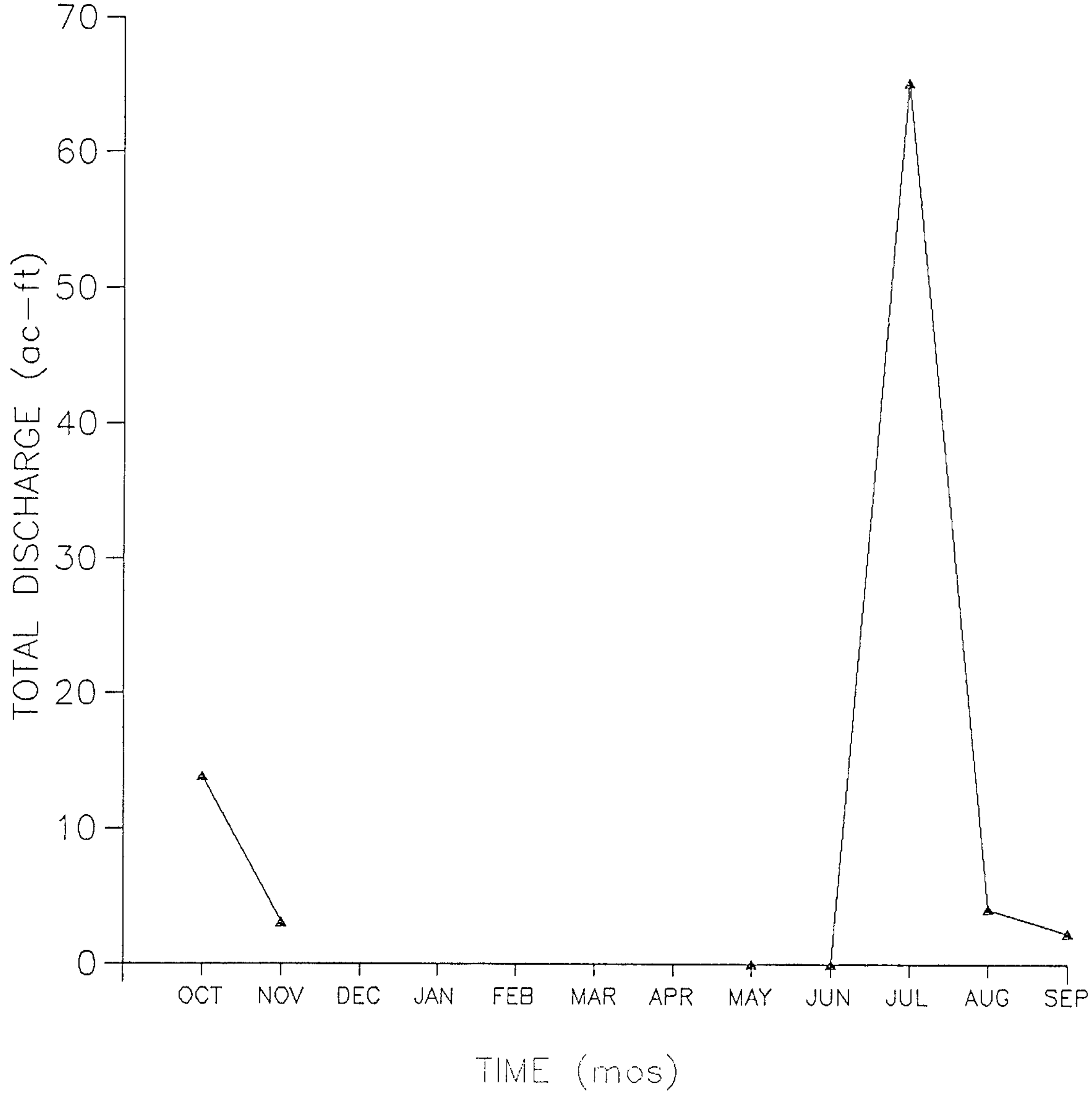

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Figure **4.1-7**

Ladora Weir
Monthly Total Discharge
WY89

CMP SW FY89

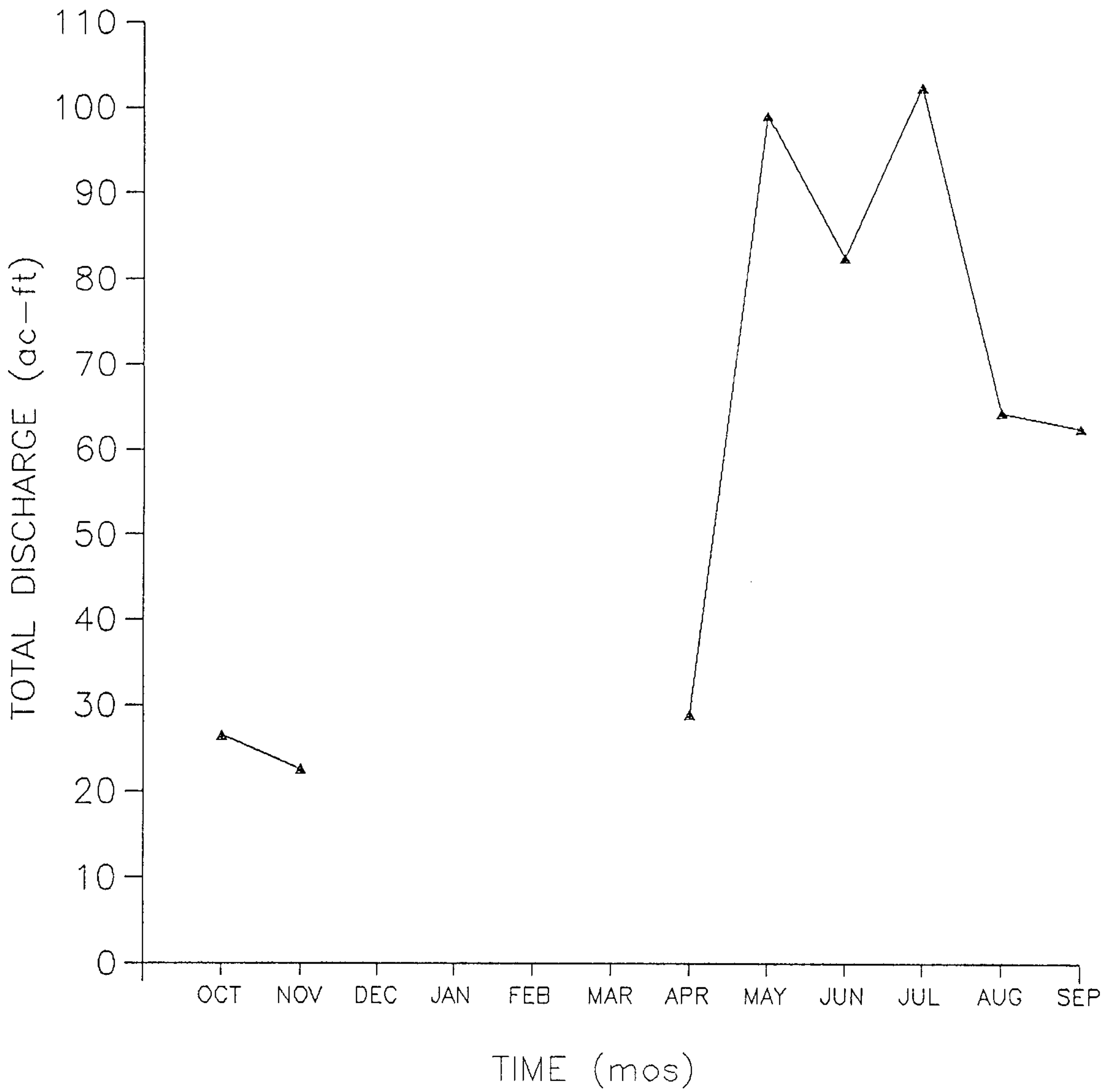

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Figure **4.1-8**

South Uvalda

Monthly Total Discharge

WY89

CMP SW FY89

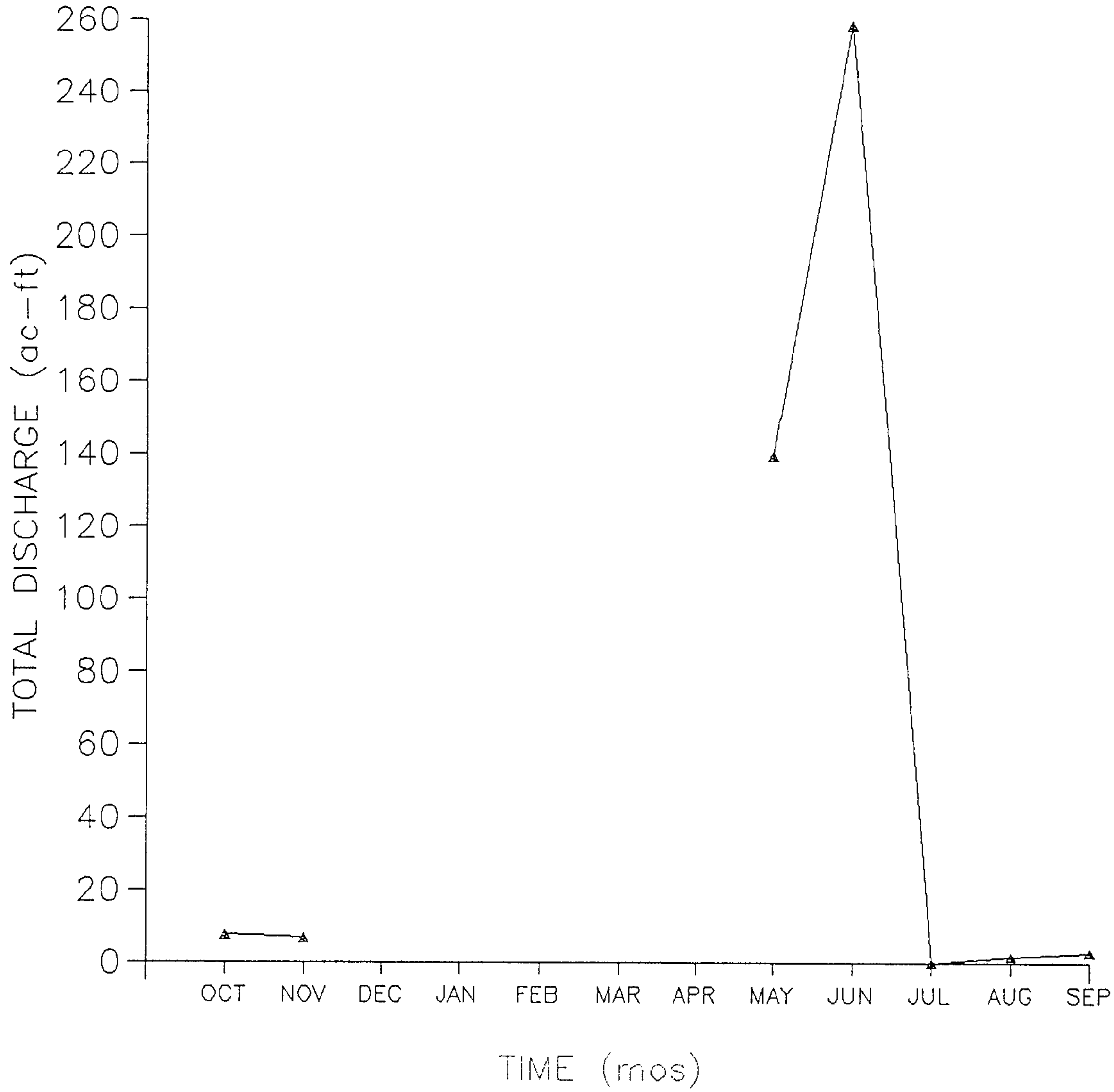

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Figure **4.1-9**

North Uvalda
Monthly Total Discharge
WY89

CMP SW FY89

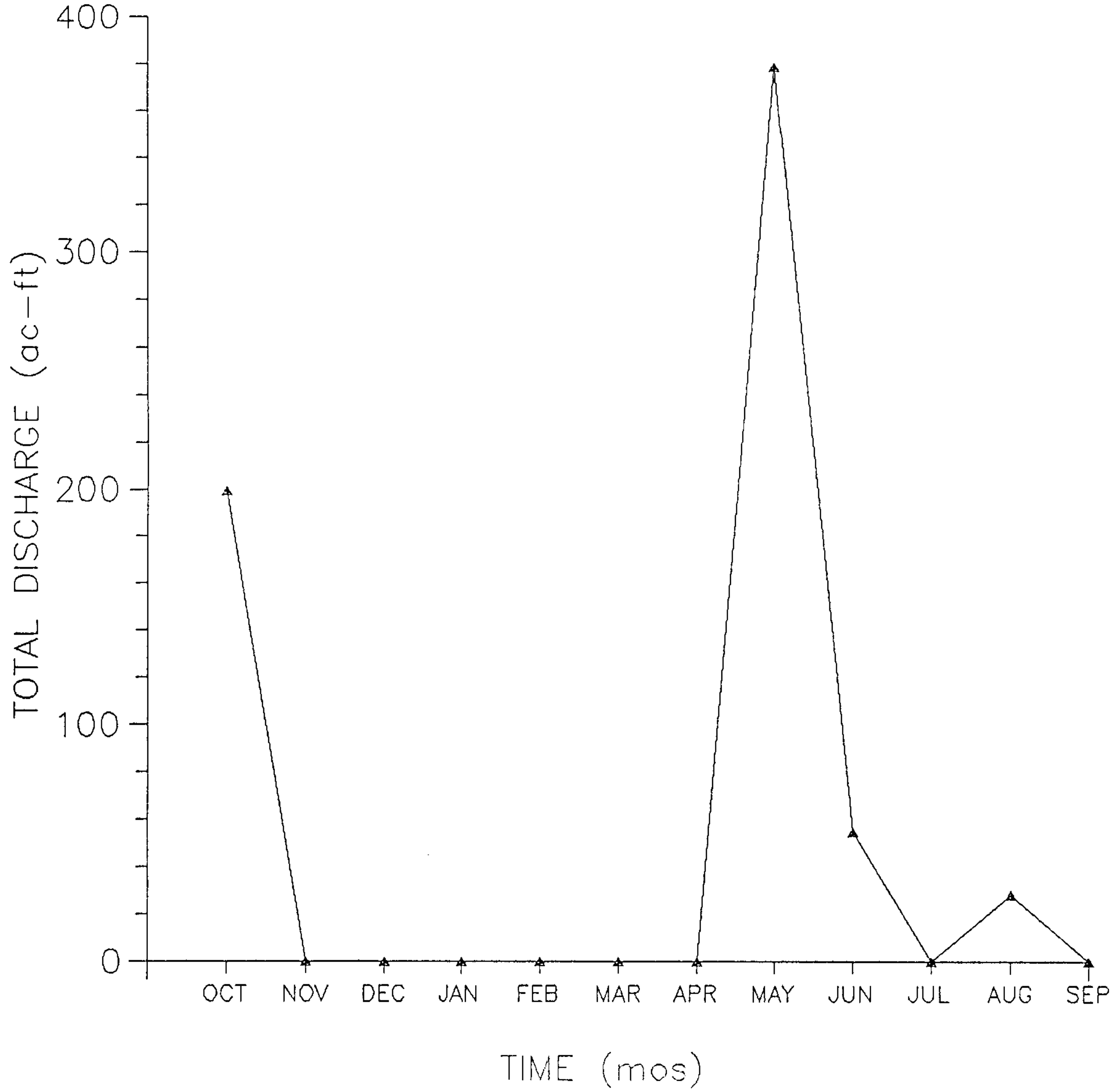

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Figure **4.1-10**

Highline Lateral

Monthly Total Discharge

WY89

CMP SW FY89

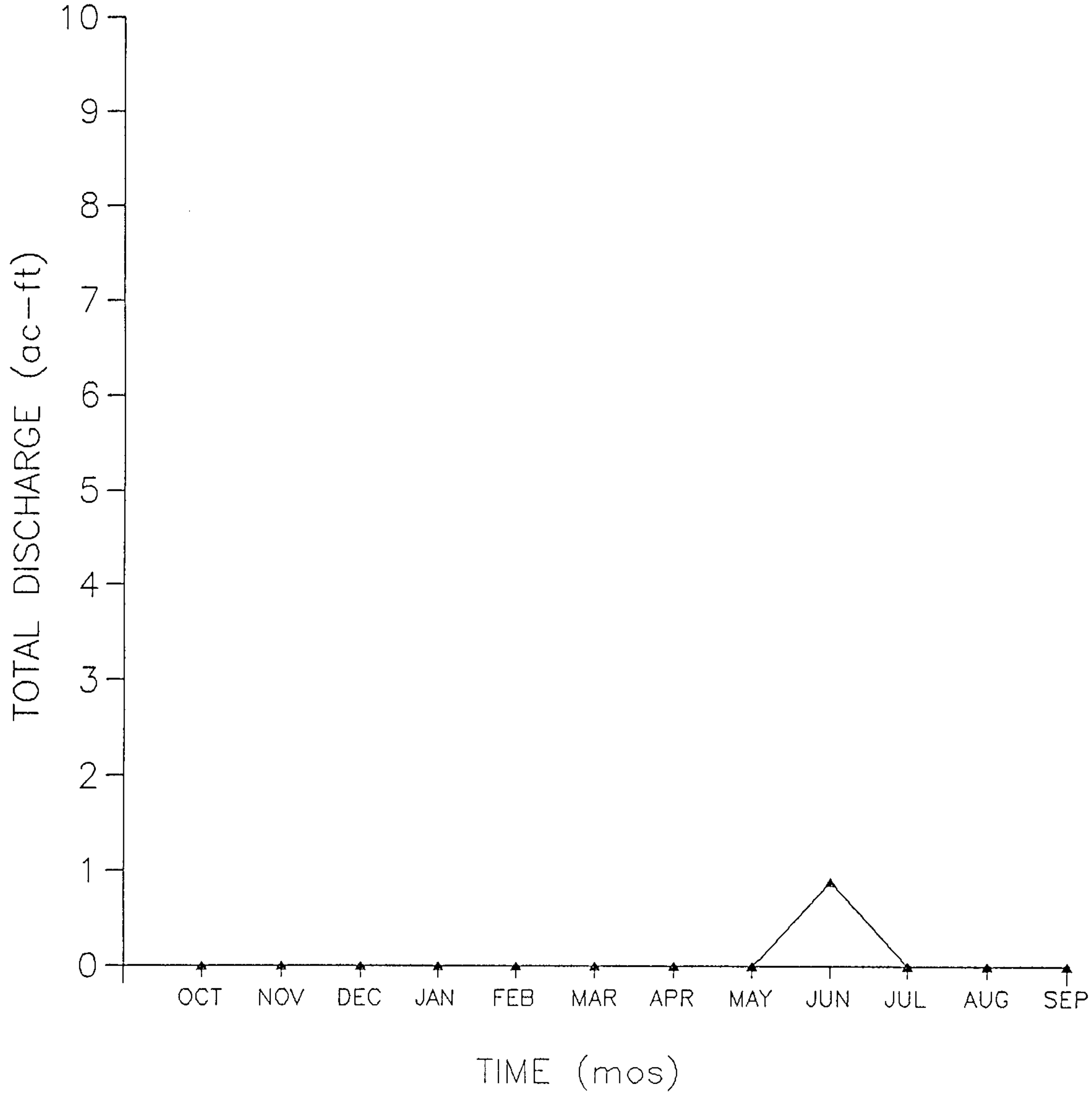

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Figure **4.1-11**

South Plants Ditch

Monthly Total Discharge

WY89

CMP SW FY89

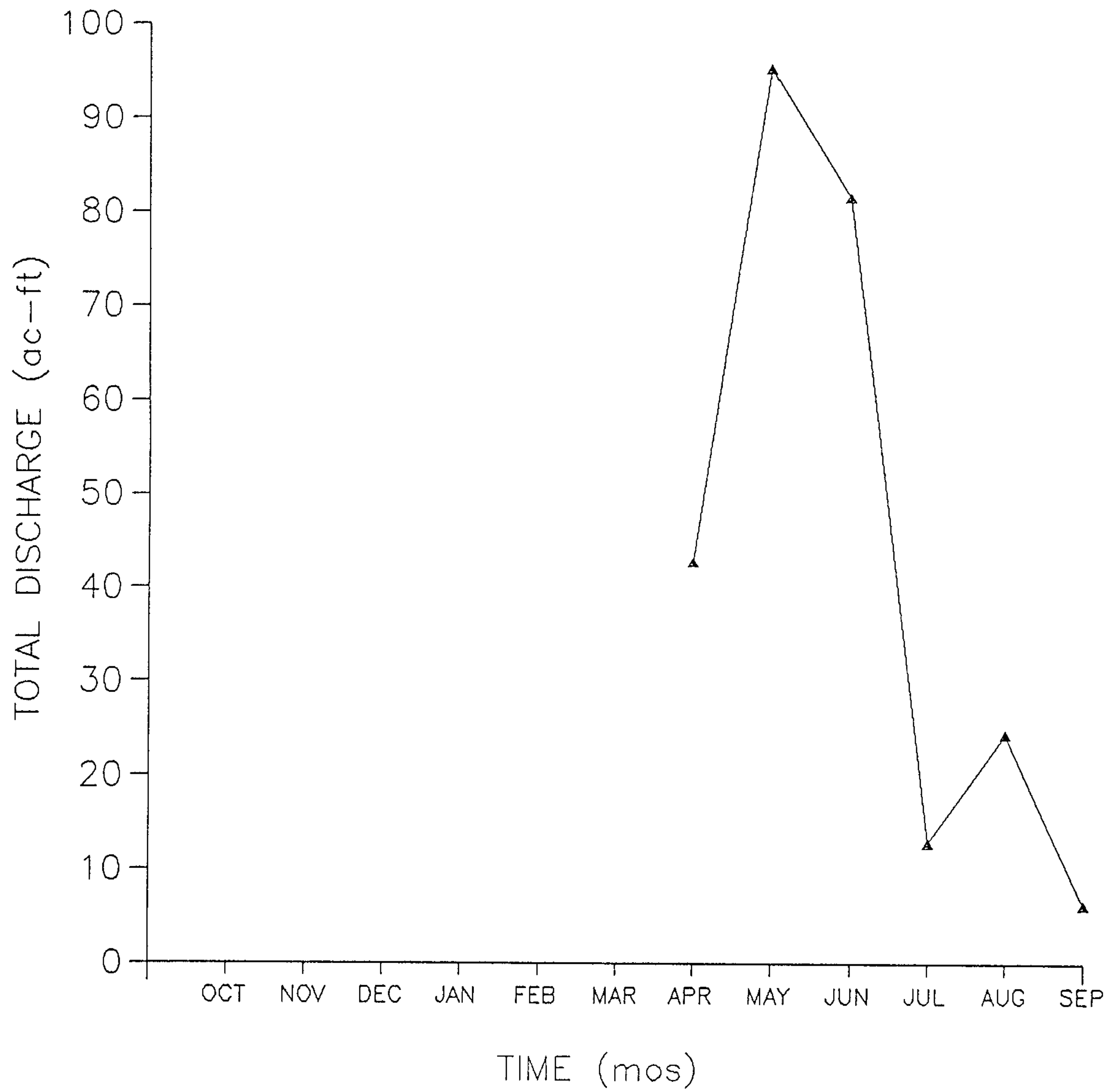

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Figure **4.1-12**

South First Creek

Monthly Total Discharge

WY89

CMP SW FY89

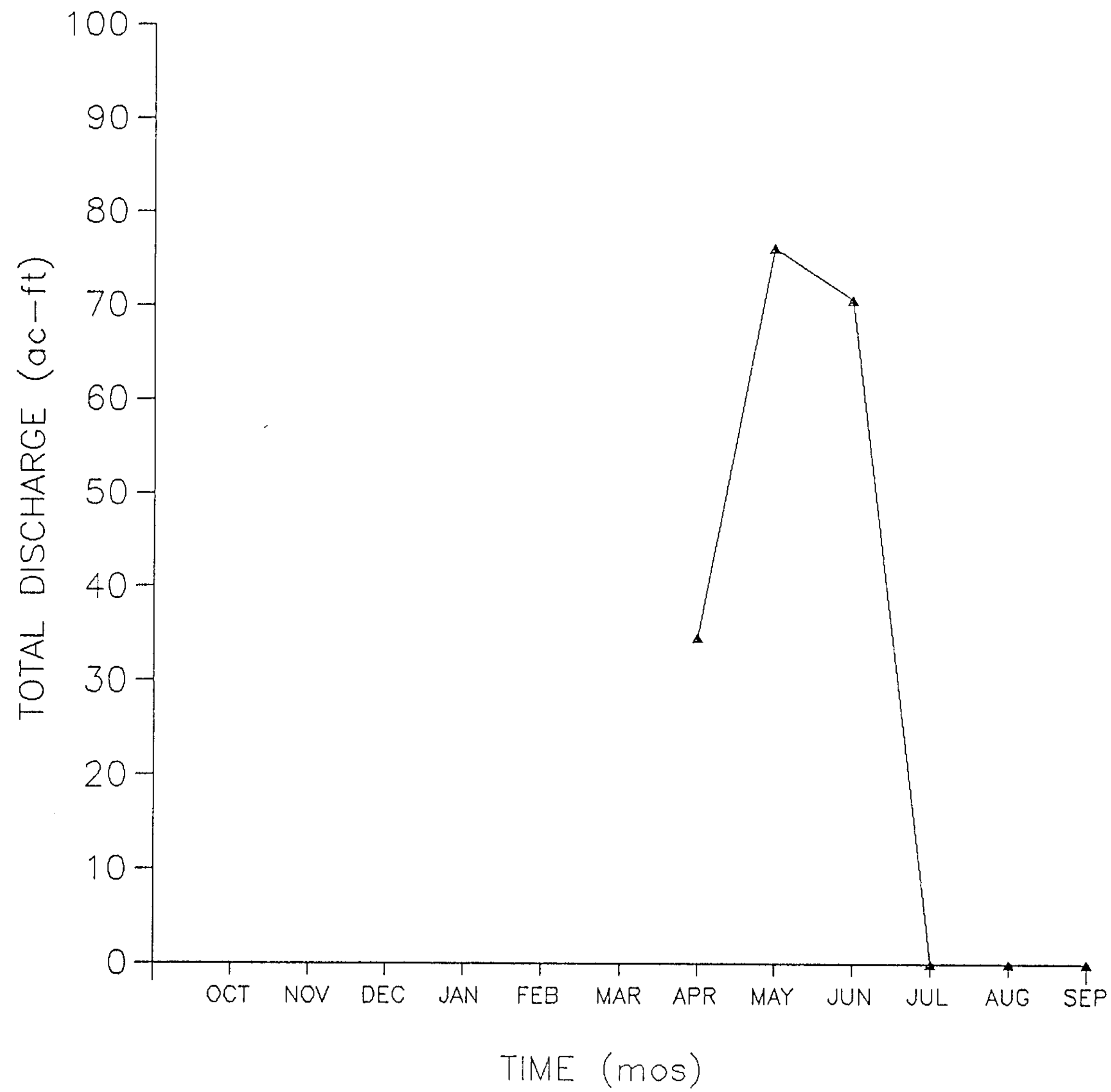

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Figure **4.1-13**

North First Creek

Monthly Total Discharge

WY89

CMP SW FY89

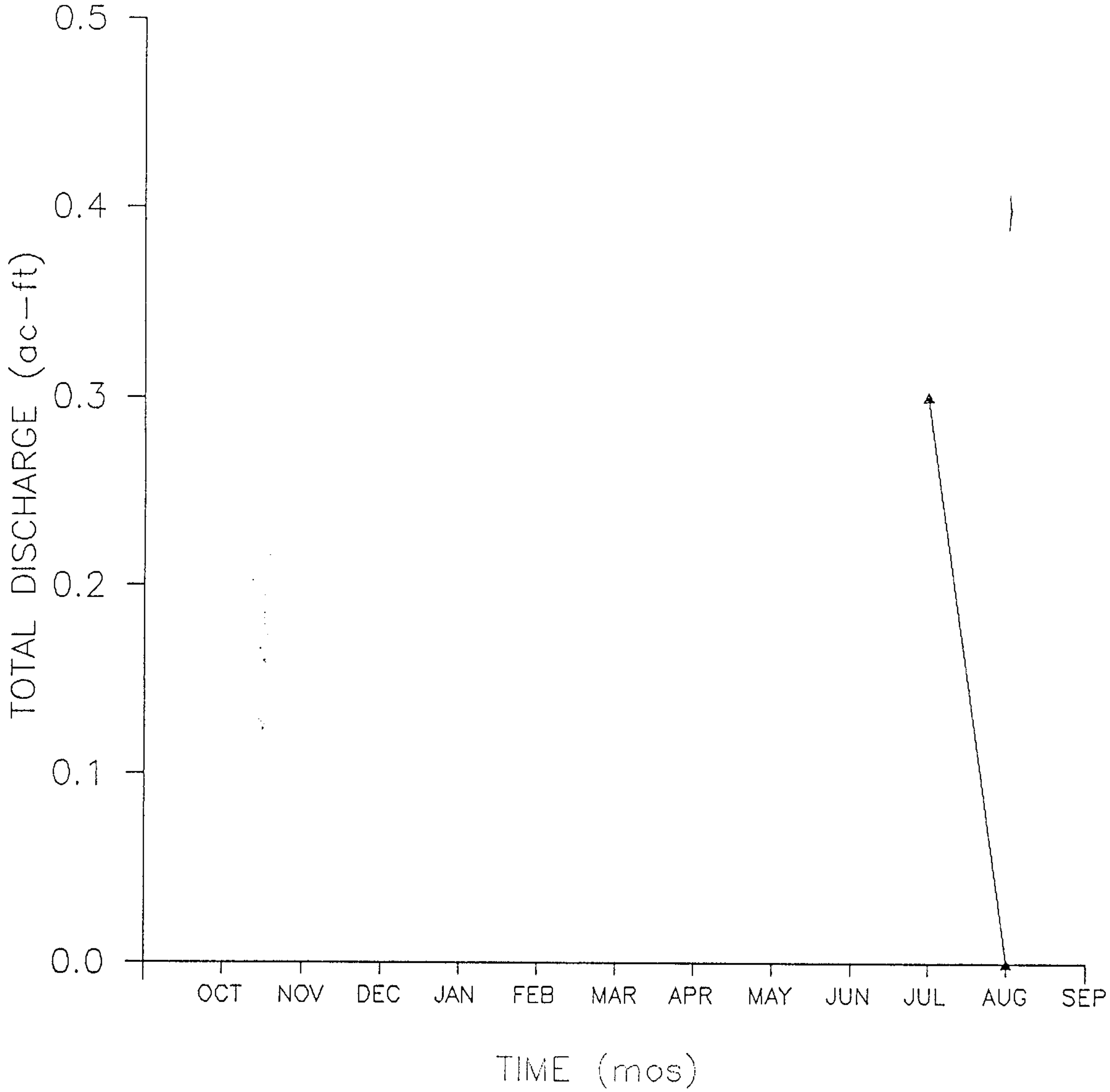

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Figure **4.1-14**

First Creek Off-Post

Monthly Total Discharge

WY89

CMP SW FY89

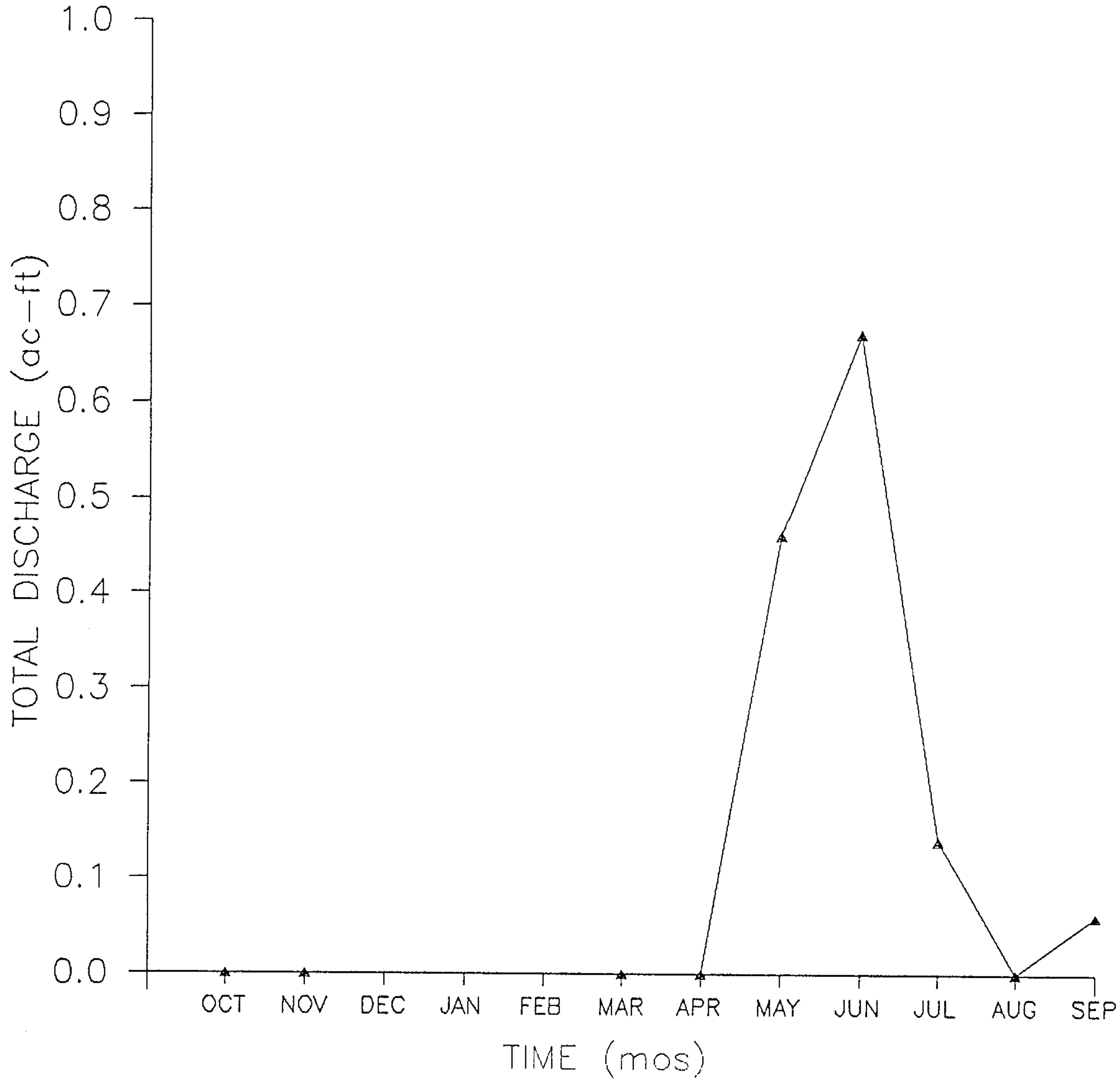

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Figure **4.1-15**

Basin A
Monthly Total Discharge
WY89

CMP SW FY89

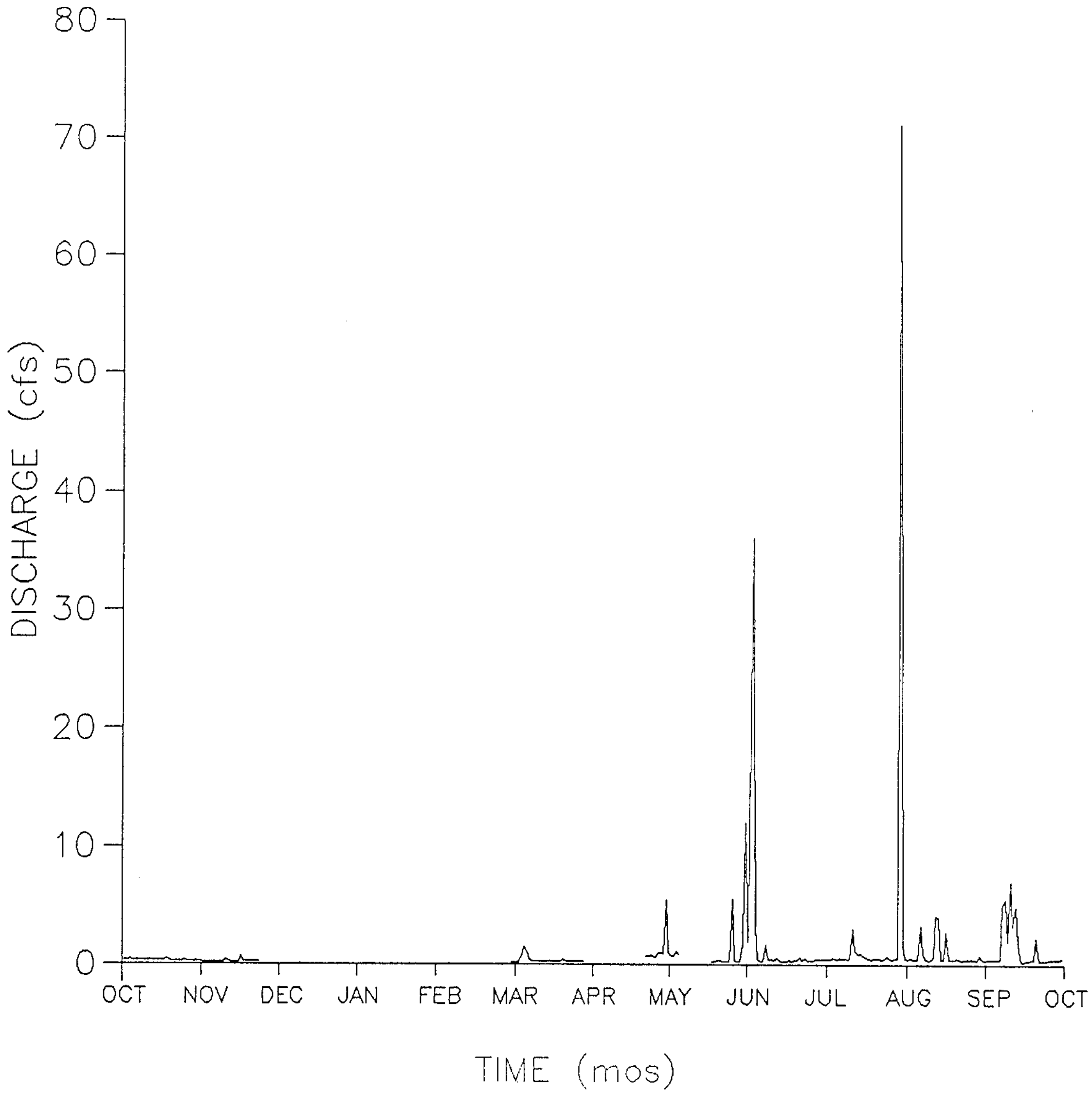

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Figure 4.1-16

Havana Interceptor
Daily Mean Discharge
Hydrograph for WY89

CMP SW FY89

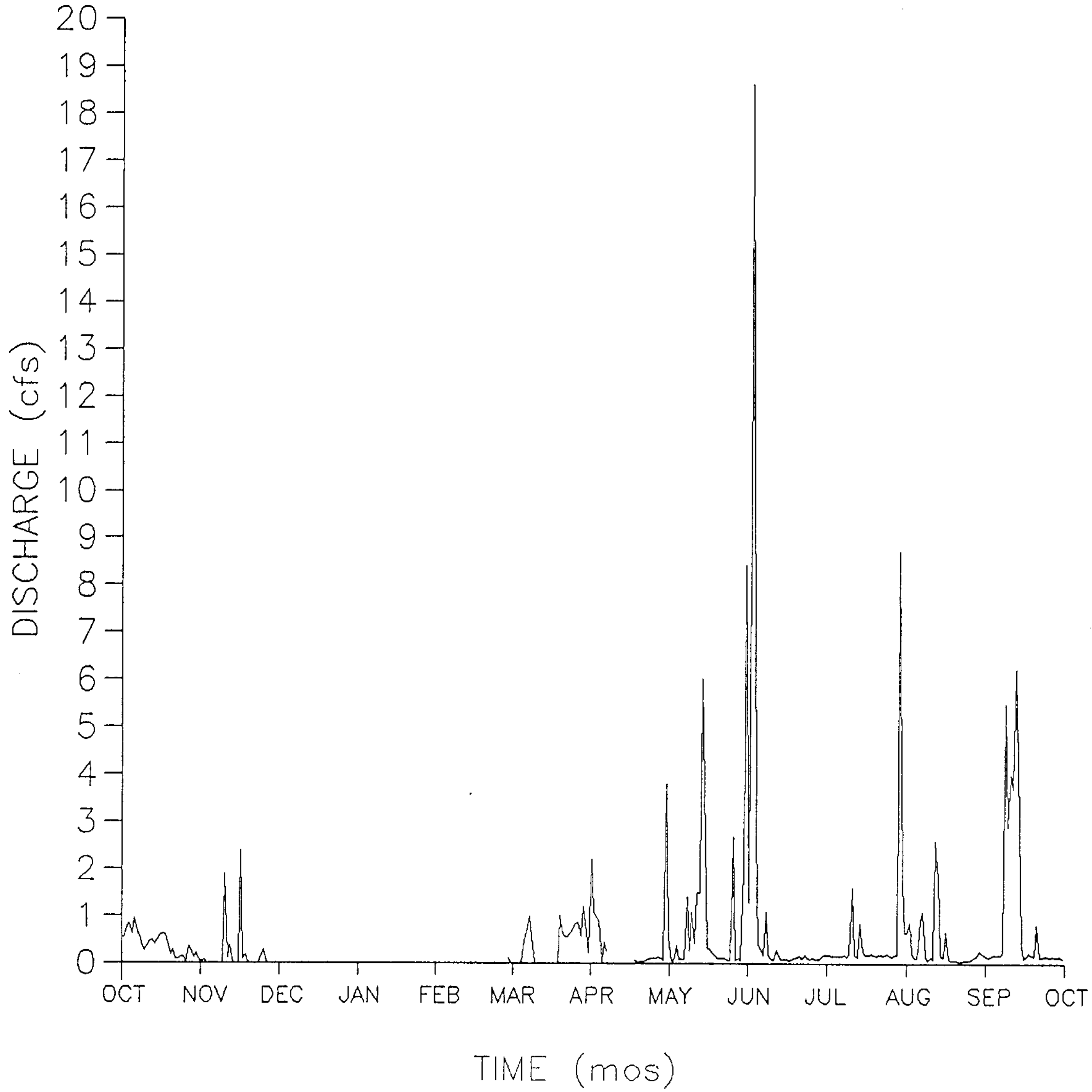

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Figure **4.1-17**

Peoria Interceptor
Daily Mean Discharge
Hydrograph for WY89

CMP SW FY89

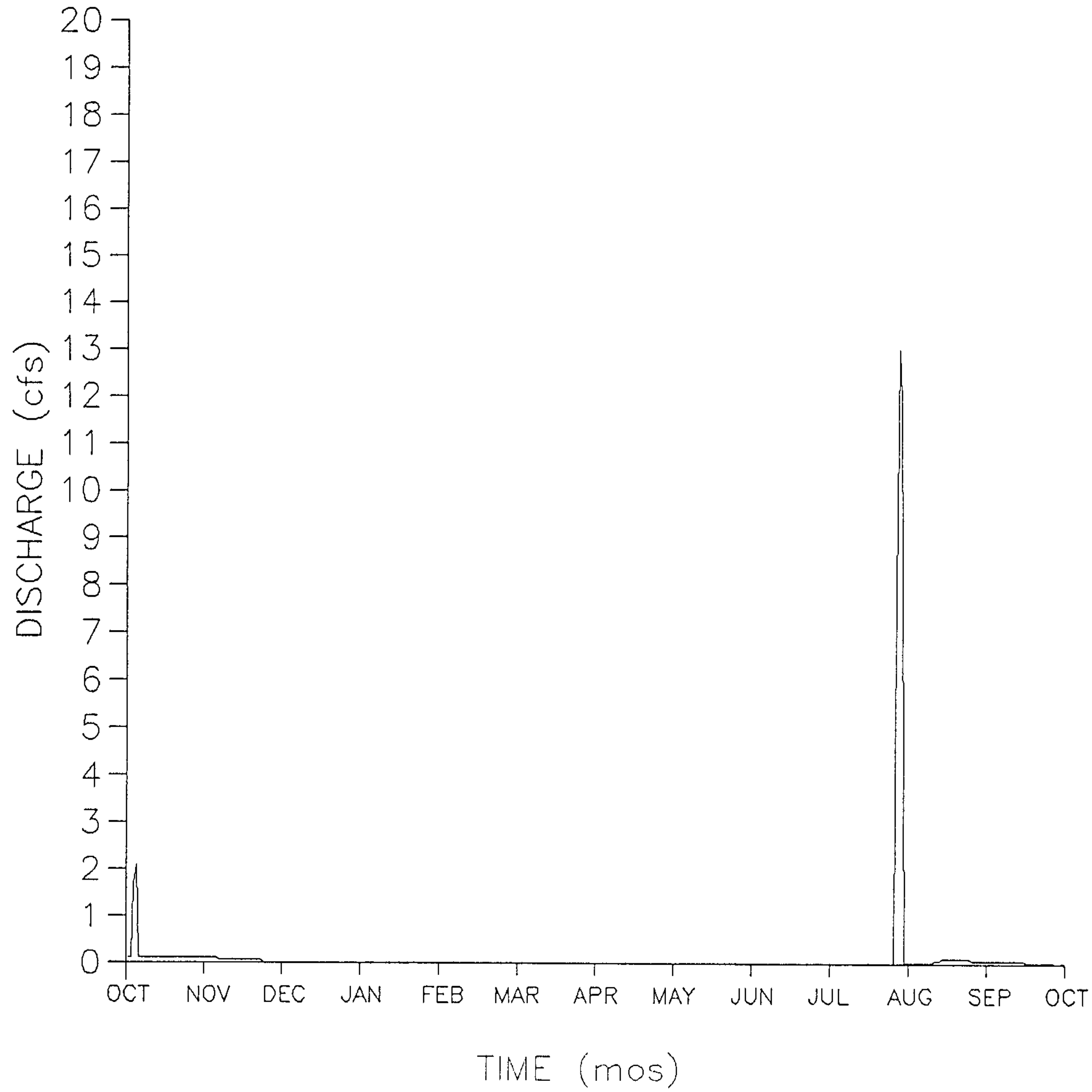

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Figure **4.1-18**

Ladora Weir

Daily Mean Discharge

Hydrograph for WY89

CMP SW FY89

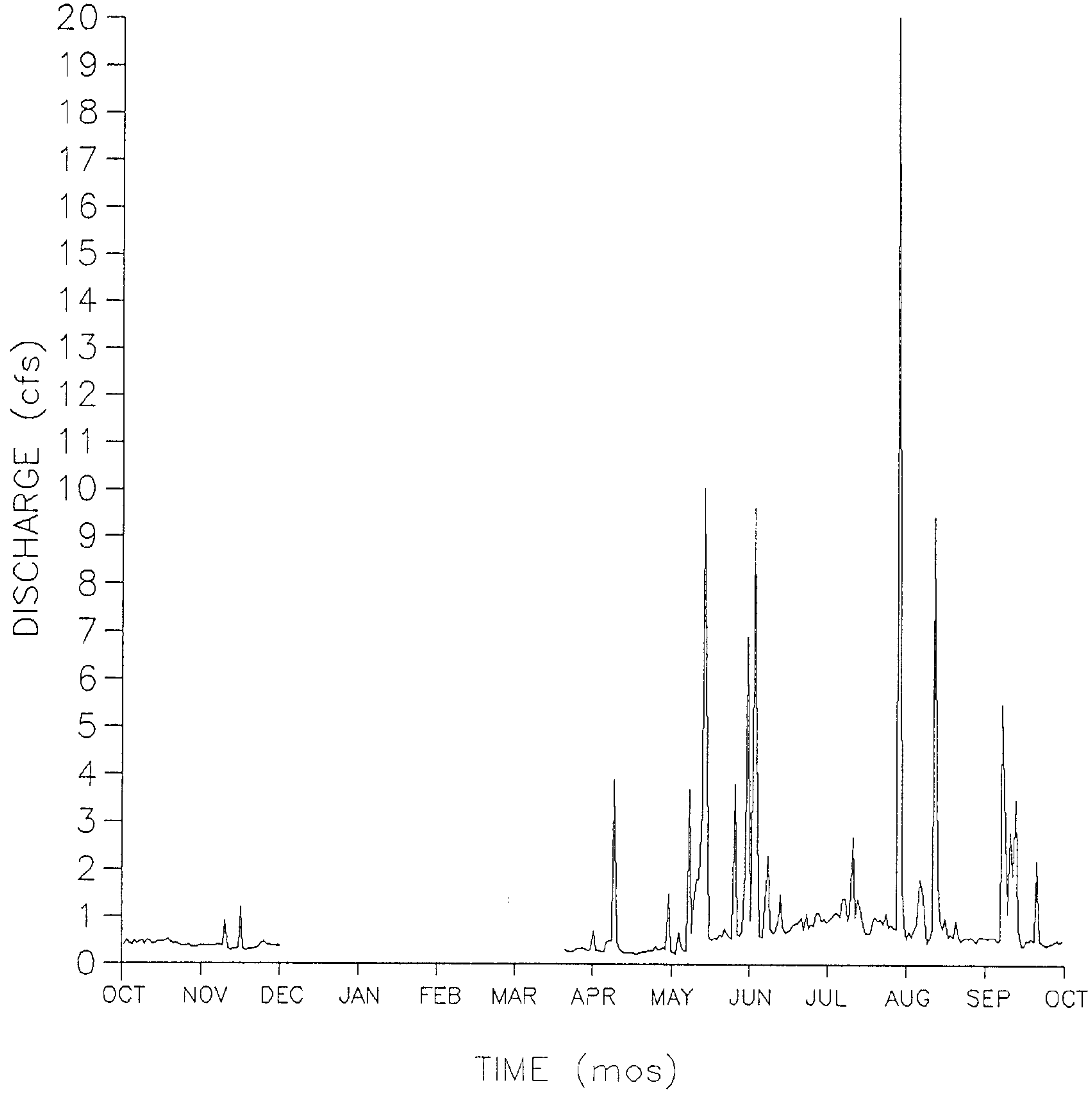

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Figure **4.1-19**

South Uvalda

Daily Mean Discharge

Hydrograph for WY89

CMP SW FY89

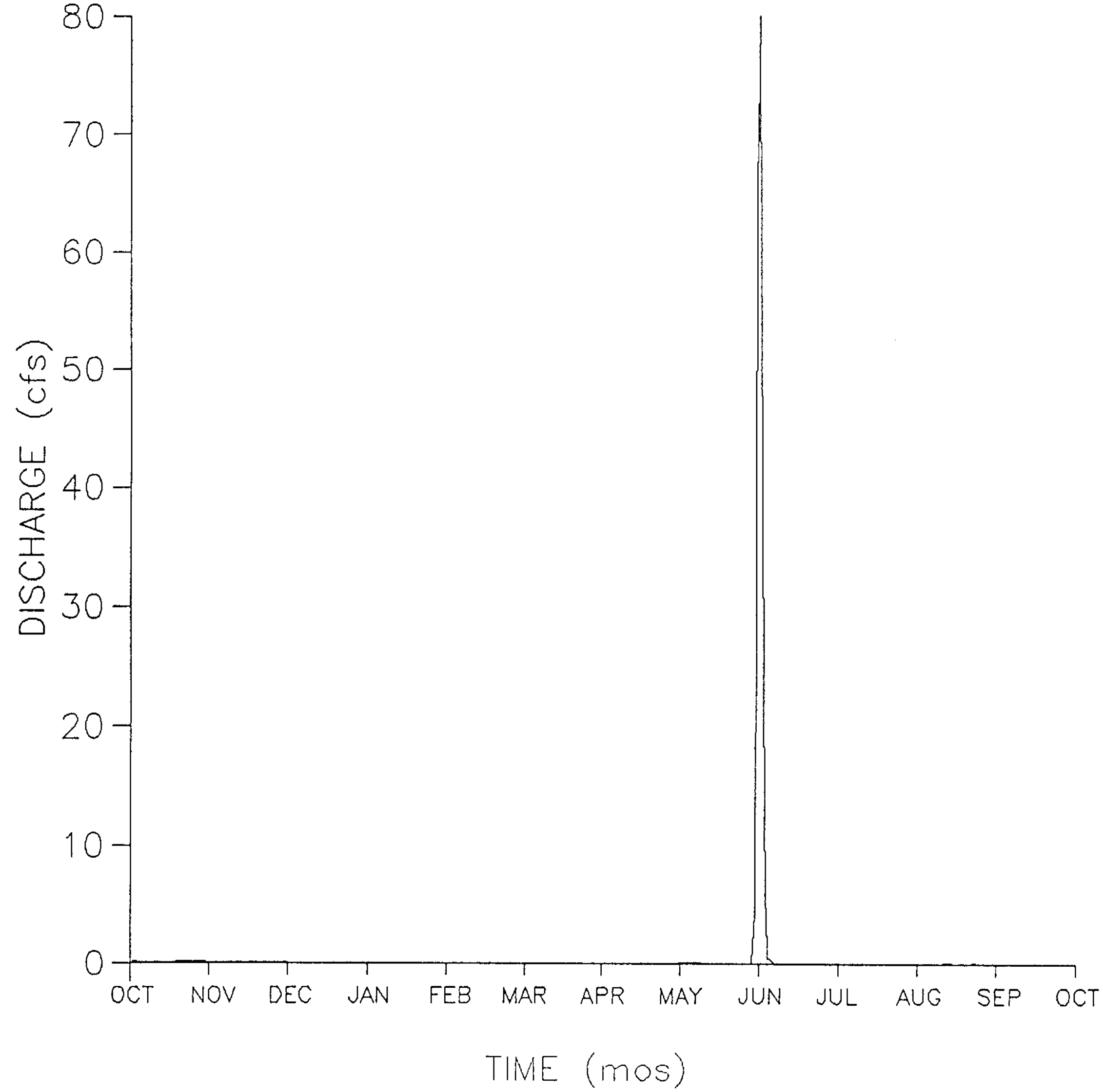

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Figure **4.1-20**

North Uvalda
Daily Mean Discharge
Hydrograph for WY89
CMP SW FY89

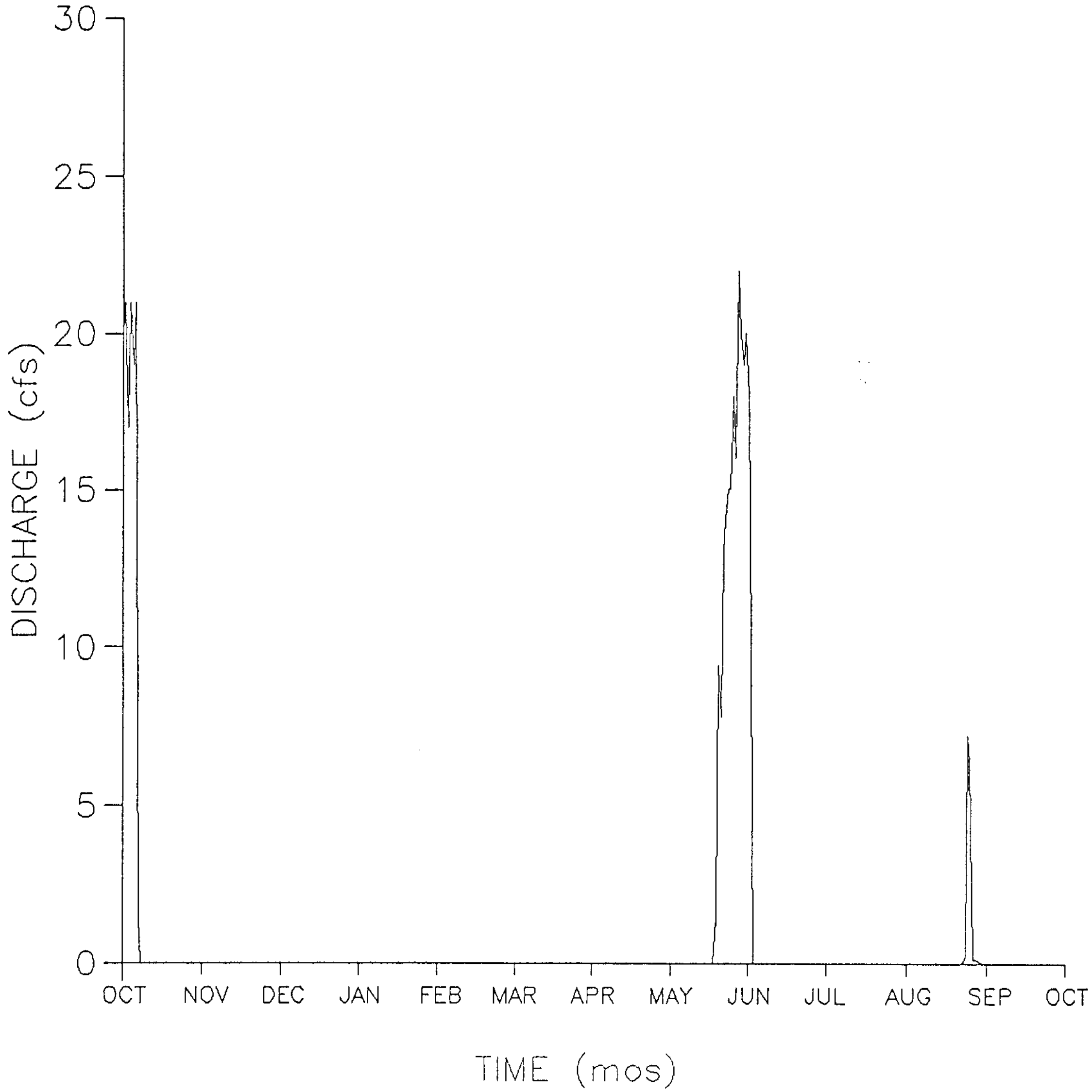

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Figure **4.1-21**

Highline Lateral
Daily Mean Discharge
Hydrograph for WY89

CMP SW FY89

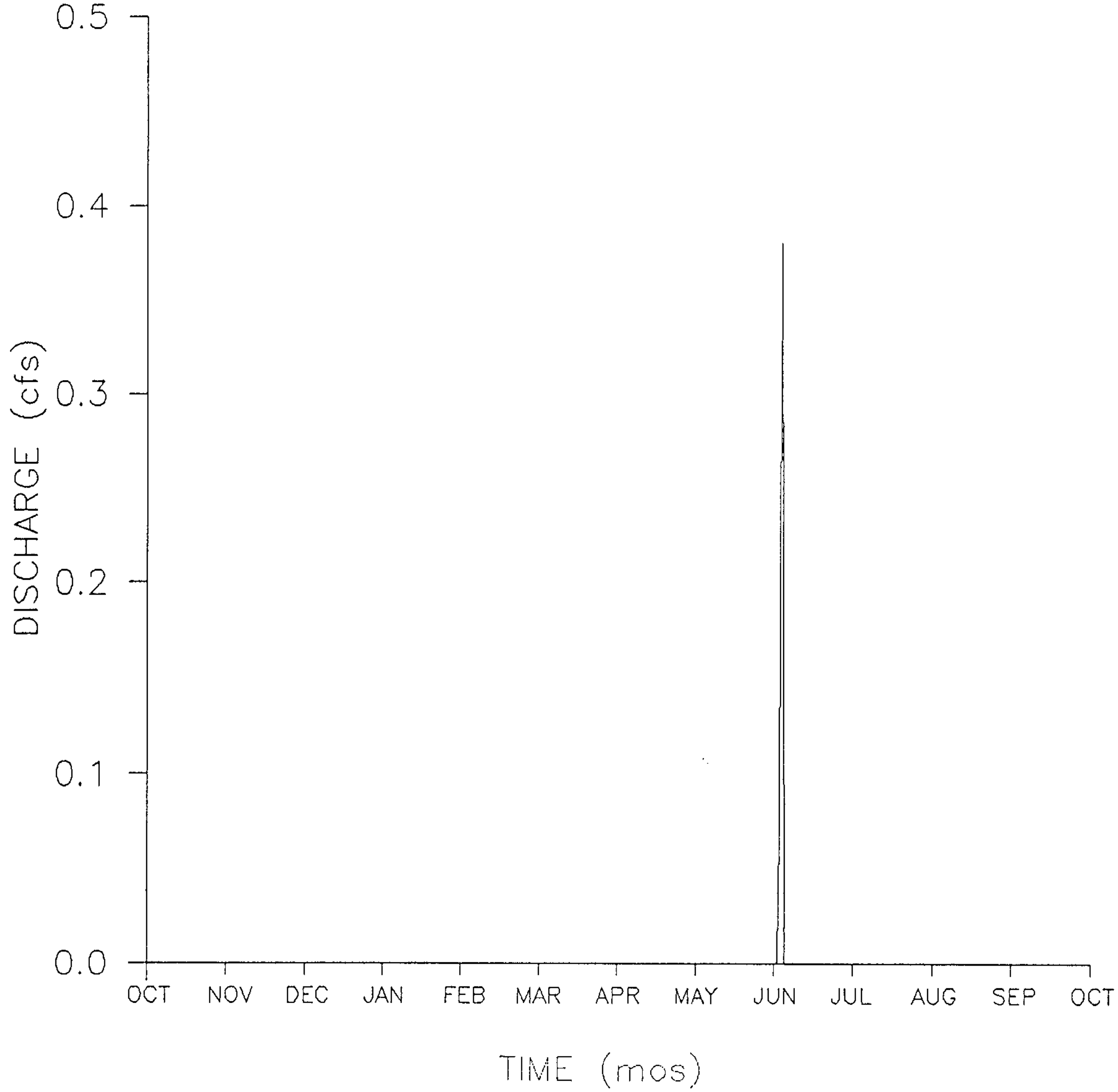

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Figure **4.1-22**

South Plants Ditch
Daily Mean Discharge
Hydrograph for WY89

CMP SW FY89

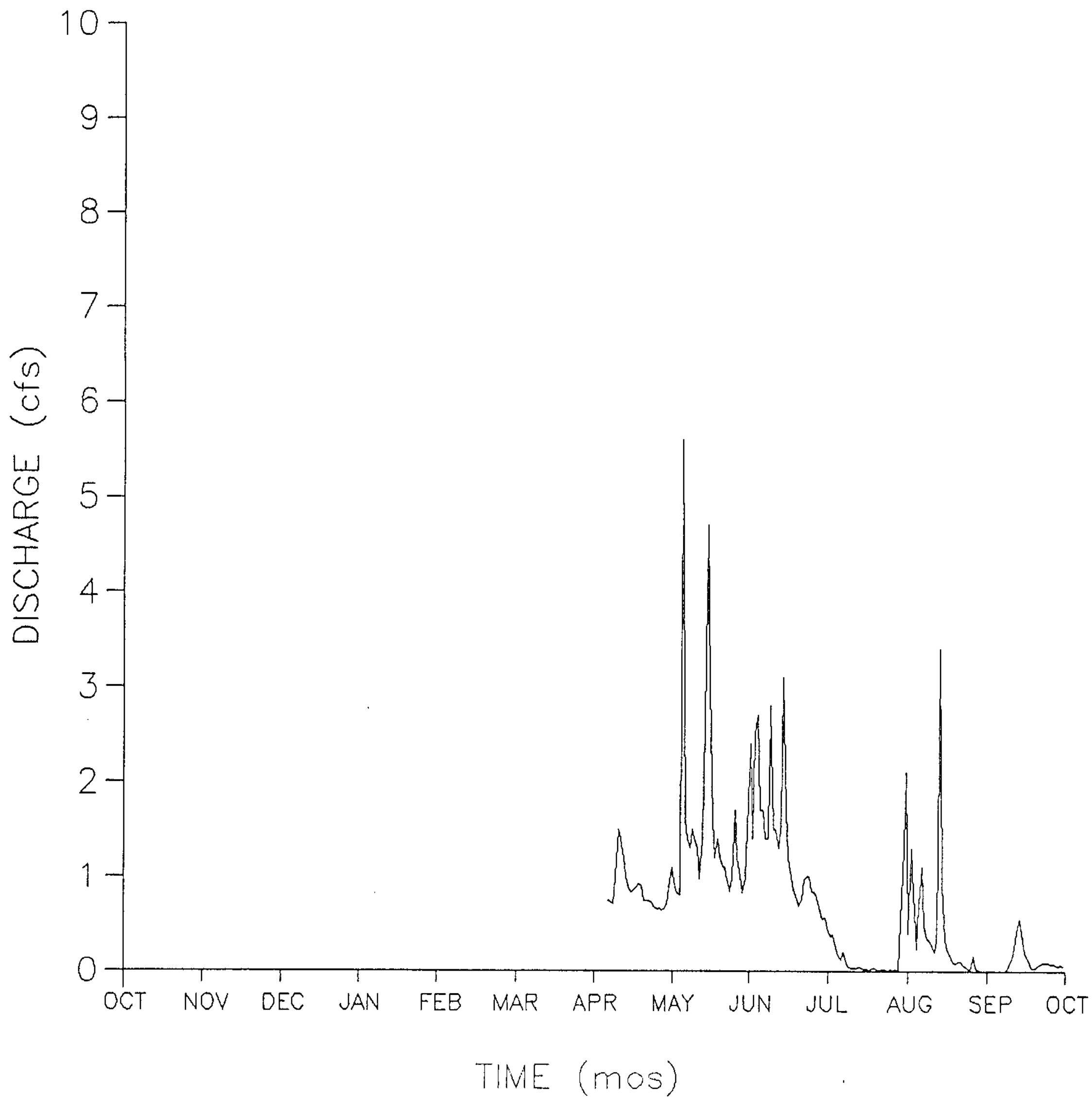

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Figure **4.1-23**

South First Creek
Daily Mean Discharge
Hydrograph for WY89

CMP SW FY89

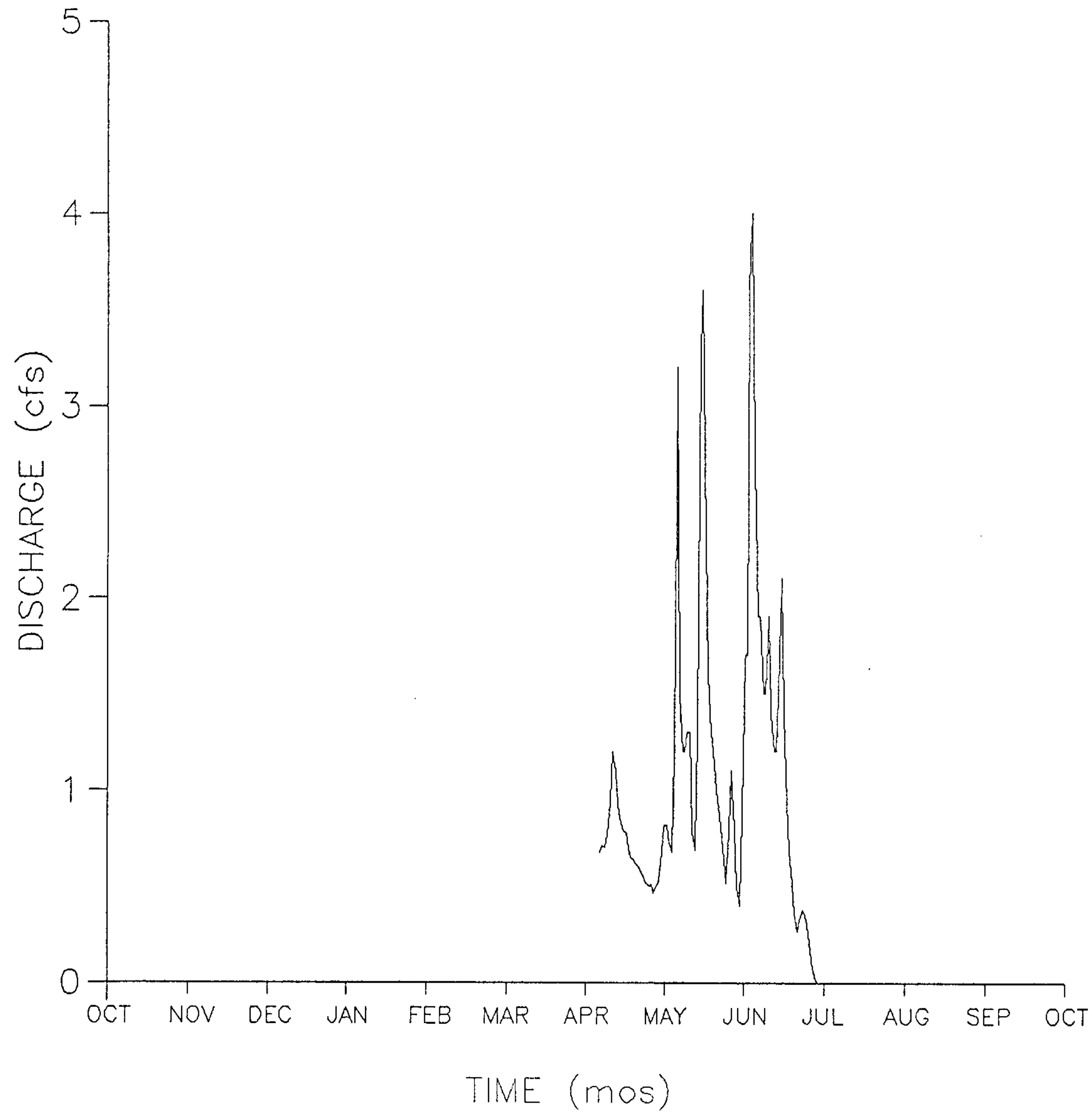

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Figure **4.1-24**

North First Creek
Daily Mean Discharge
Hydrograph for WY89

CMP SW FY89

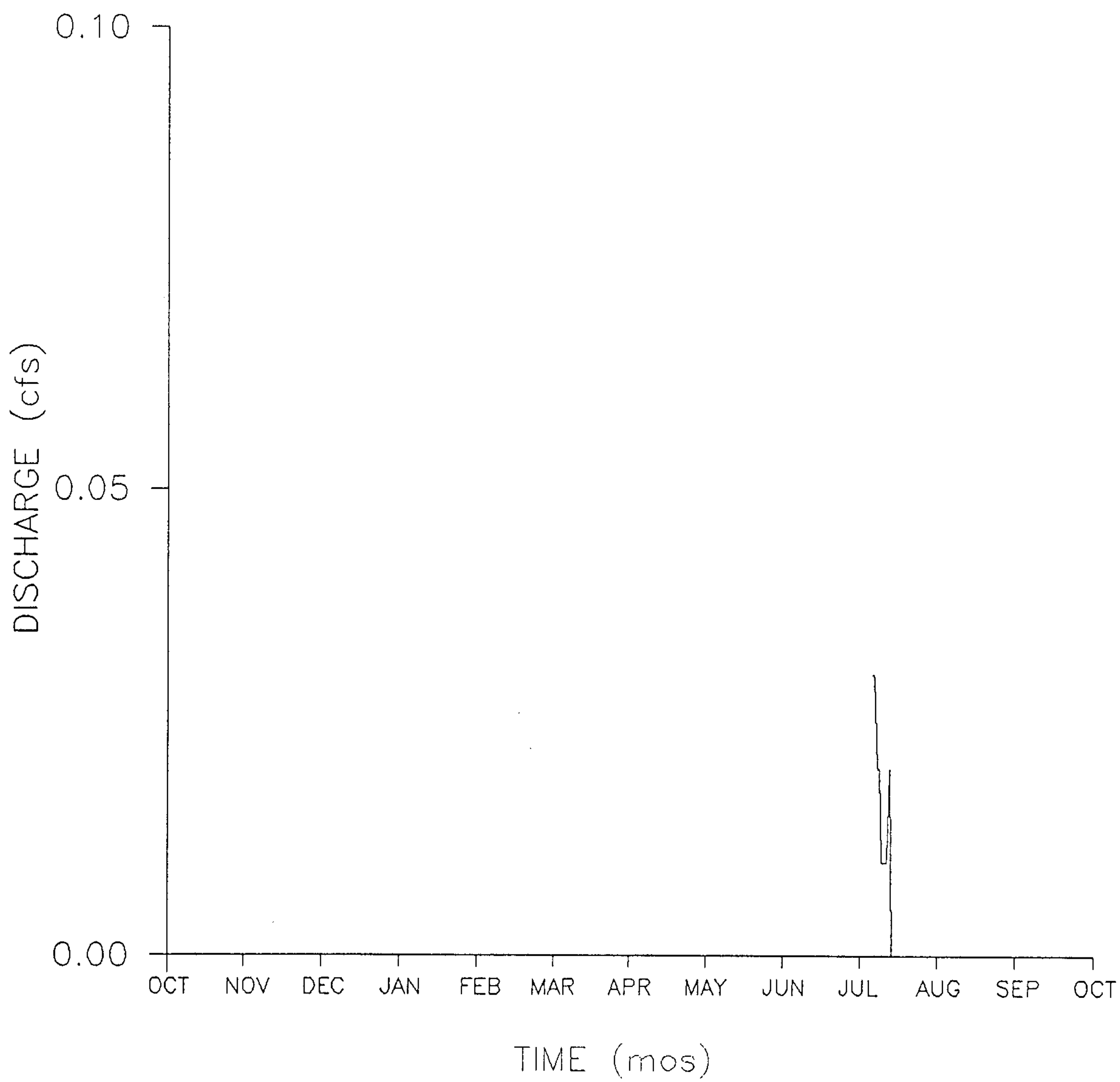

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Figure **4.1-25**
First Creek Off-Post
Daily Mean Discharge
Hydrograph for WY89

CMP SW FY89

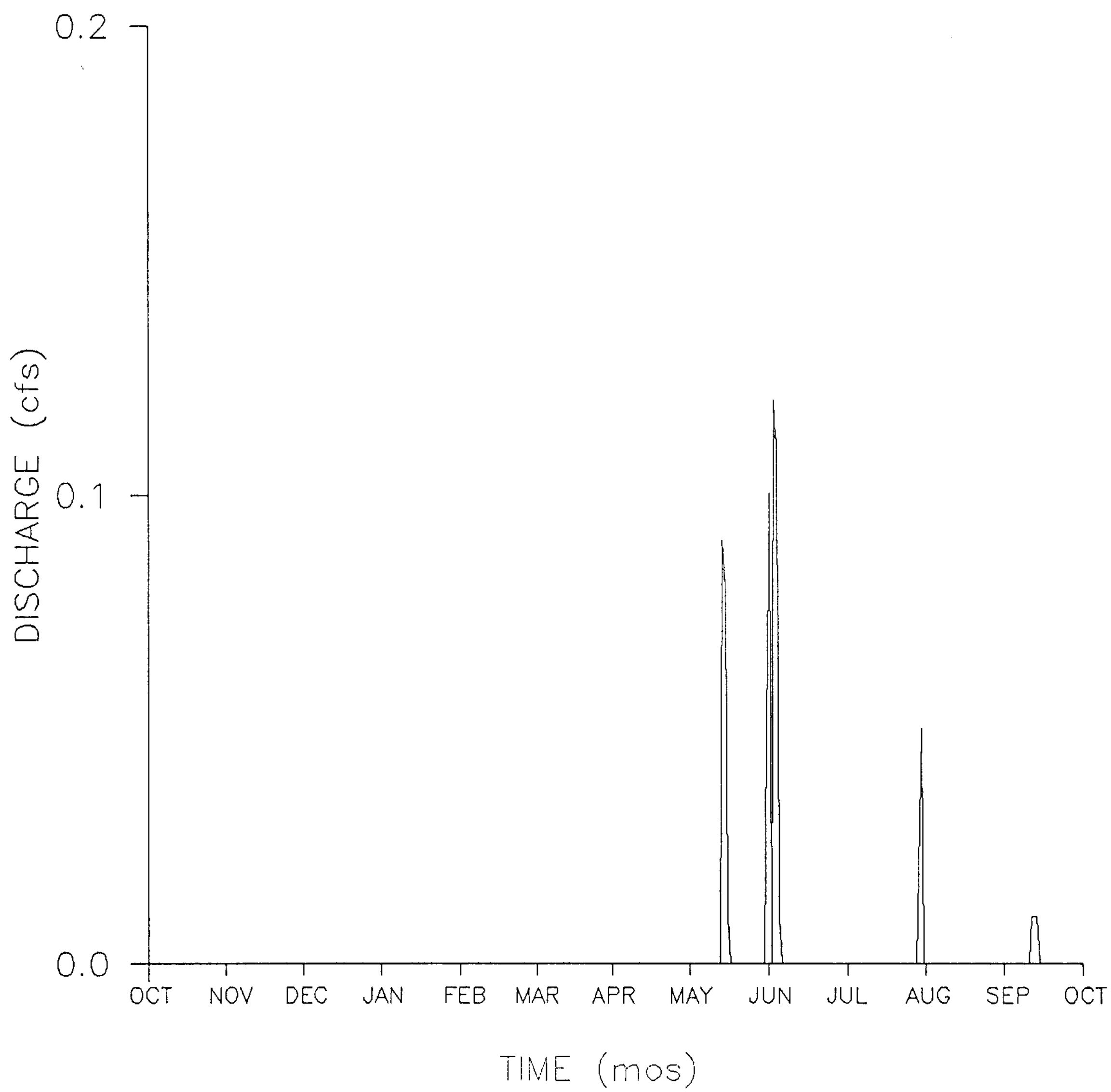

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Figure **4.1-26**

Basin A

Daily Mean Discharge

Hydrograph for WY89

CMP SW FY89

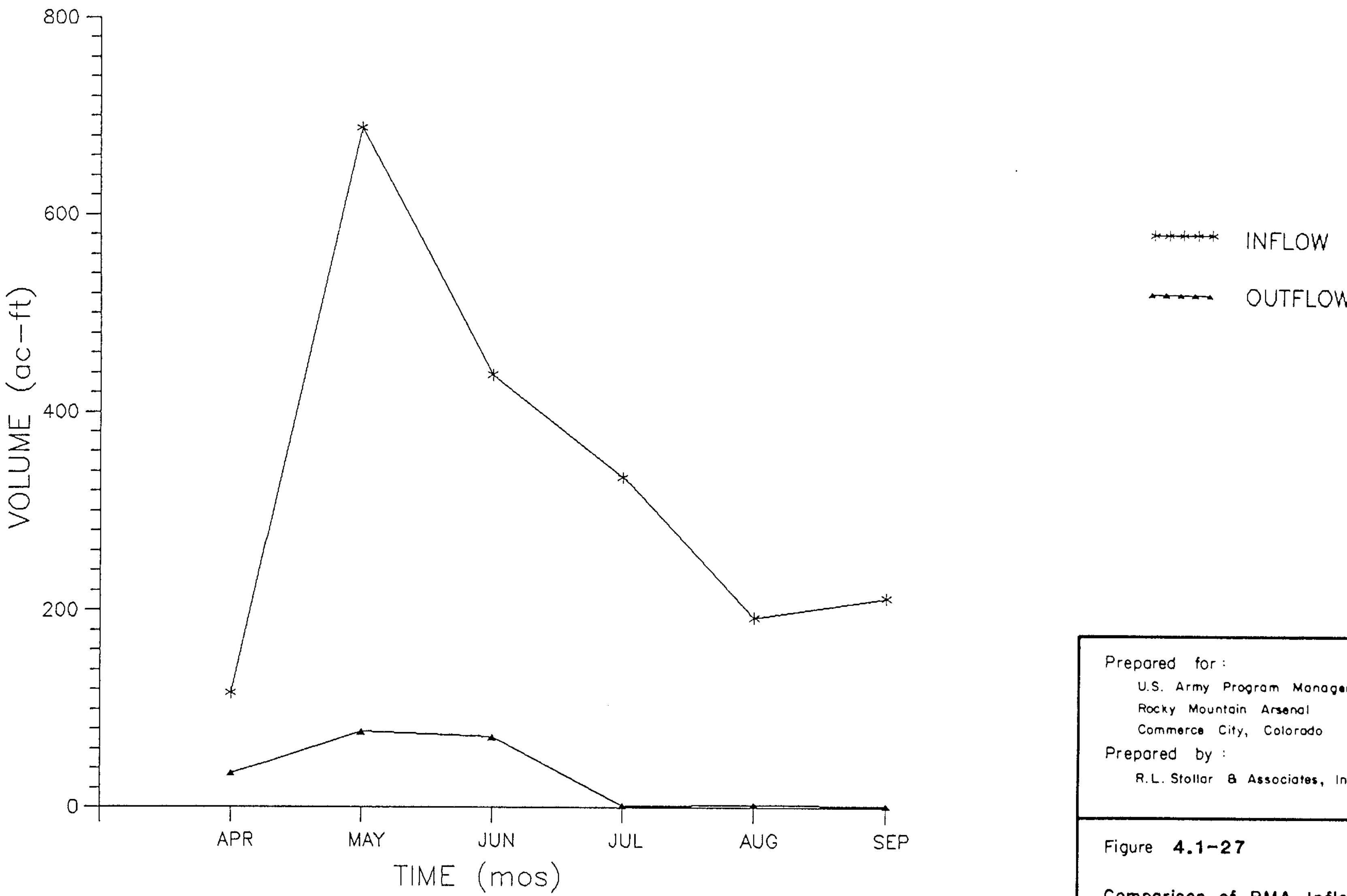

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Figure **4.1-27**

Comparison of RMA Inflow and Outflow Volumes

CMP SW FY89

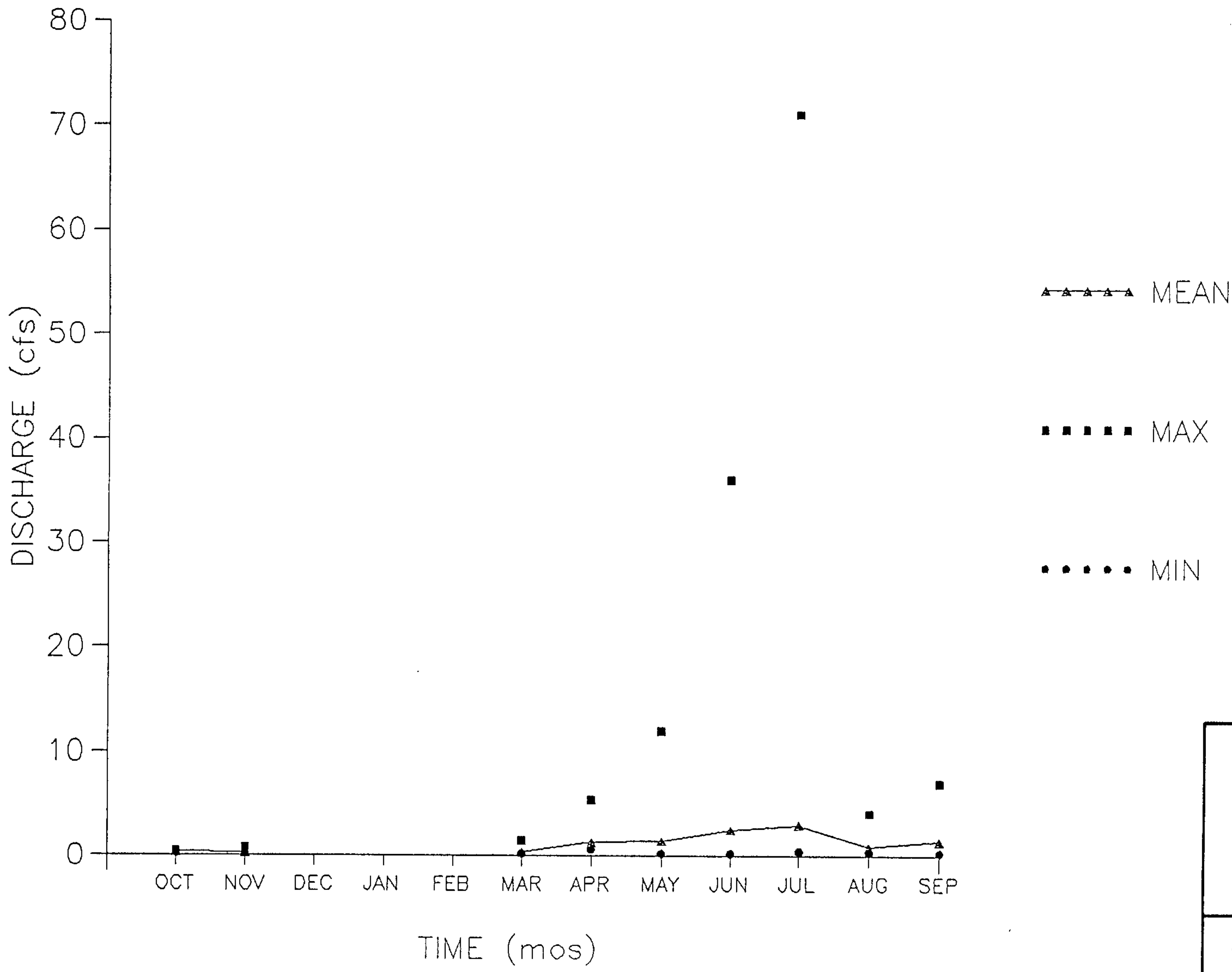

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Figure **4.1-28**

Havana Interceptor
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY89
CMP SW FY89

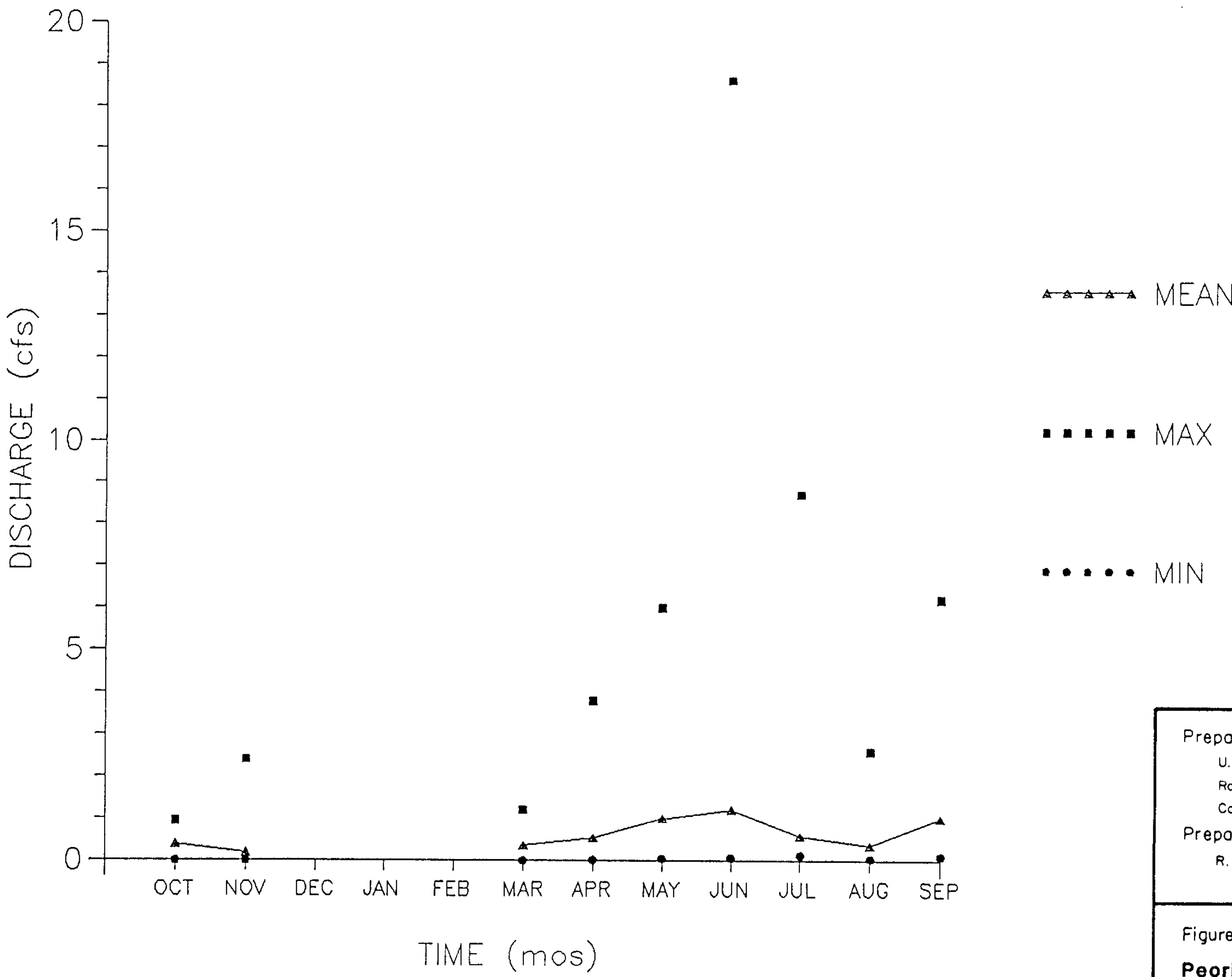

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Figure **4.1-29**

Peoria Interceptor
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY89
CMP SW FY89

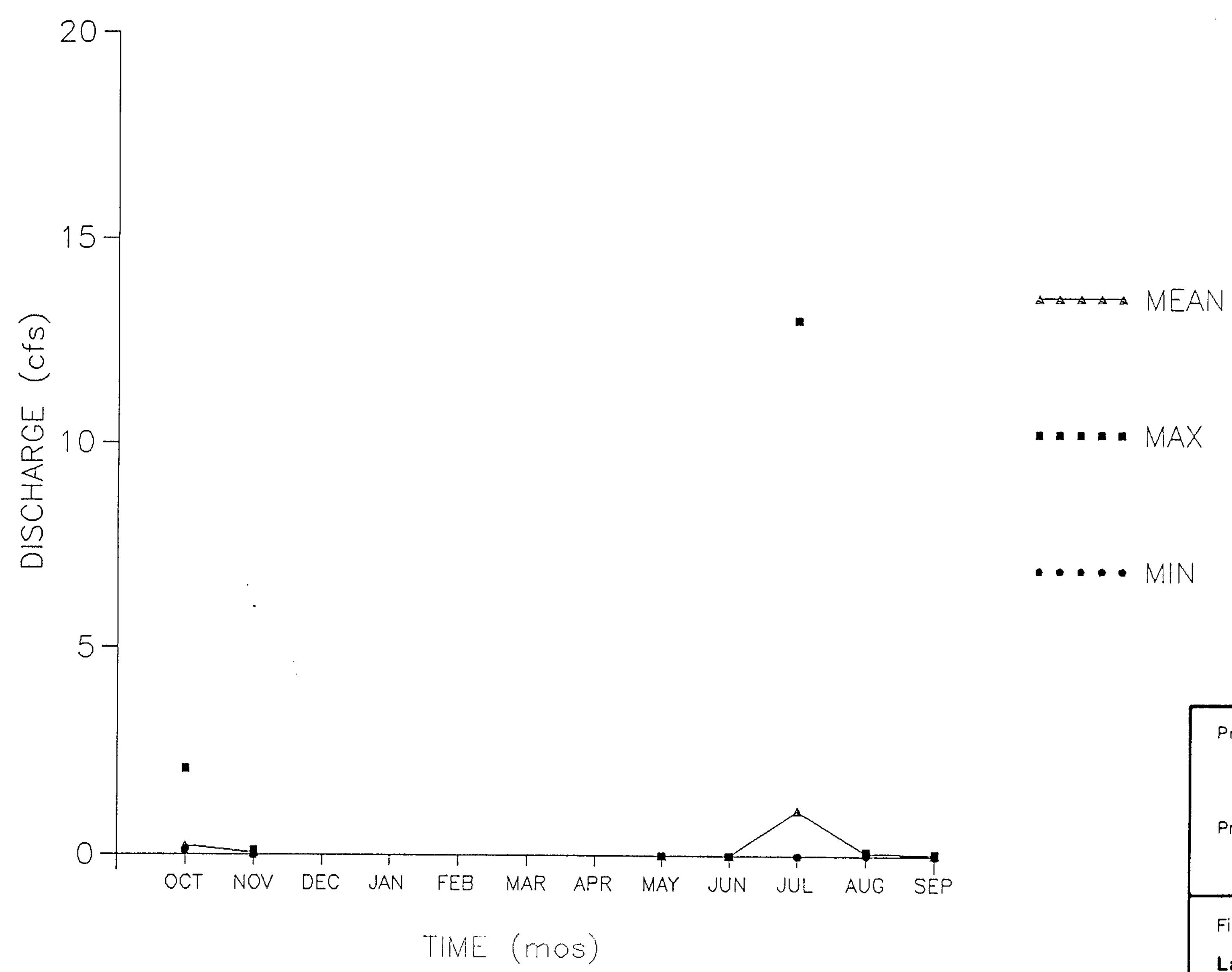

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Figure **4.1-30**

Ladora Weir
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY89
CMP SW FY89

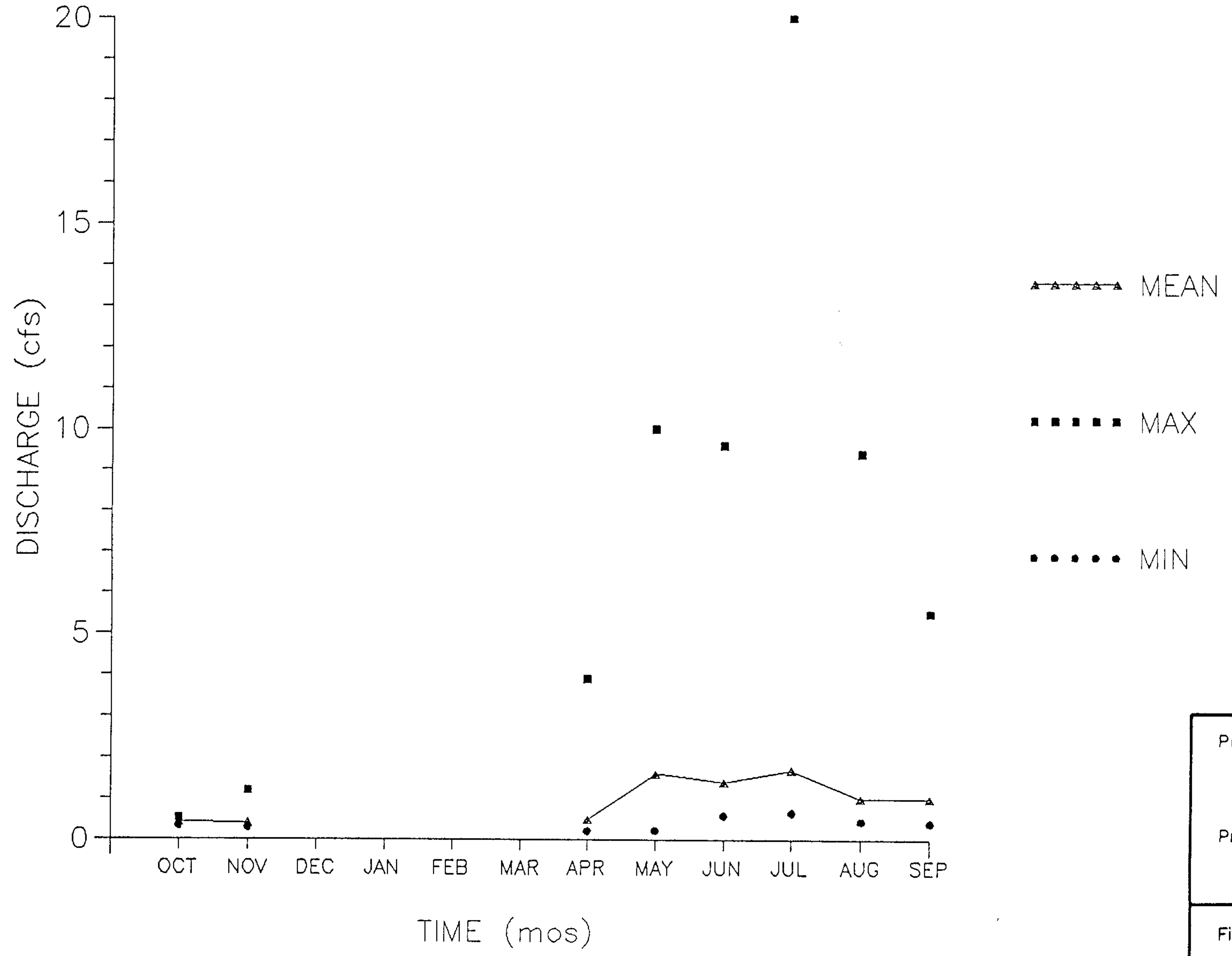

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Figure 4.1-31
South Uvalda
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY89
CMP SW FY89

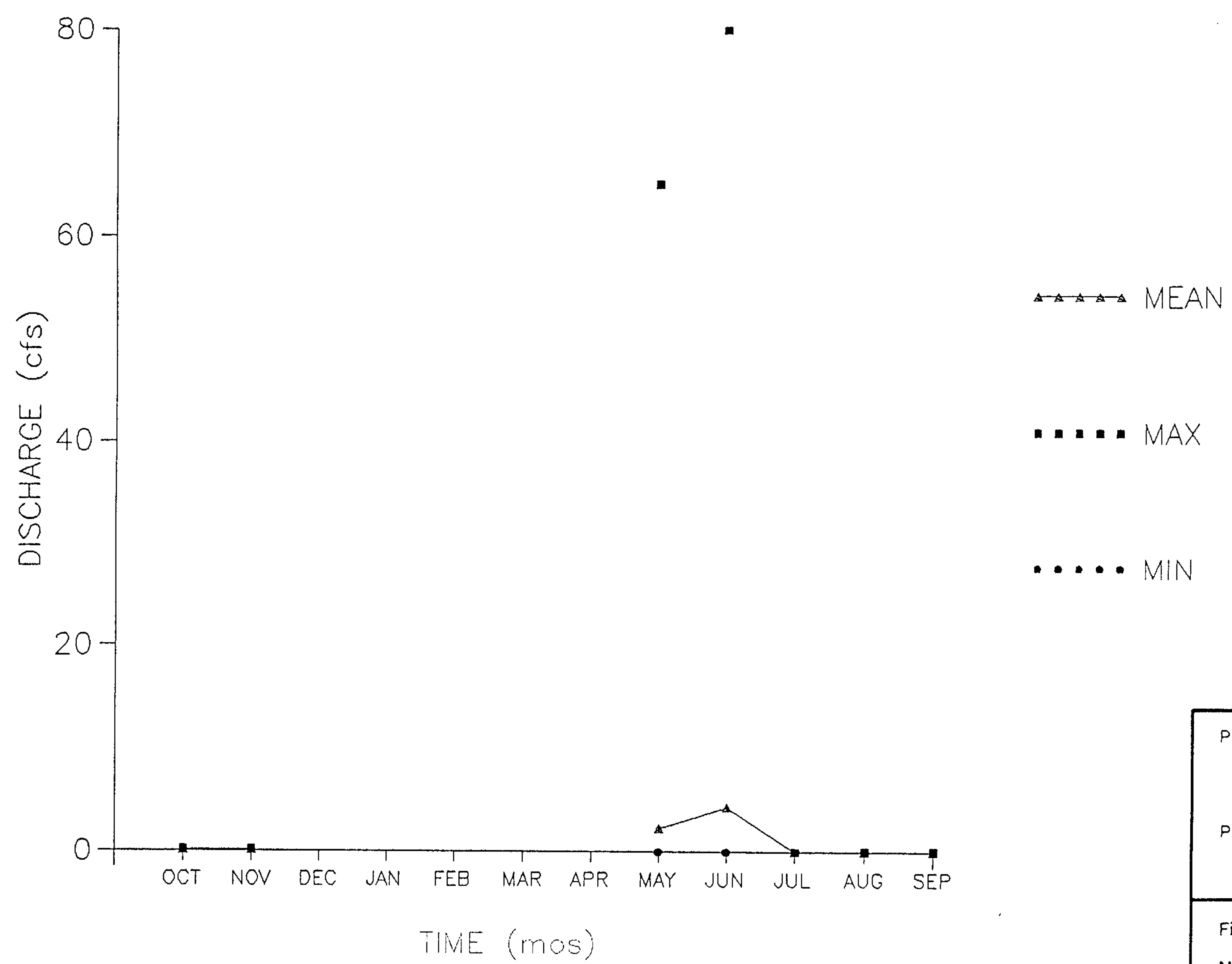

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Figure 4.1-32

North Uvalda
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY89

CMP SW FY89

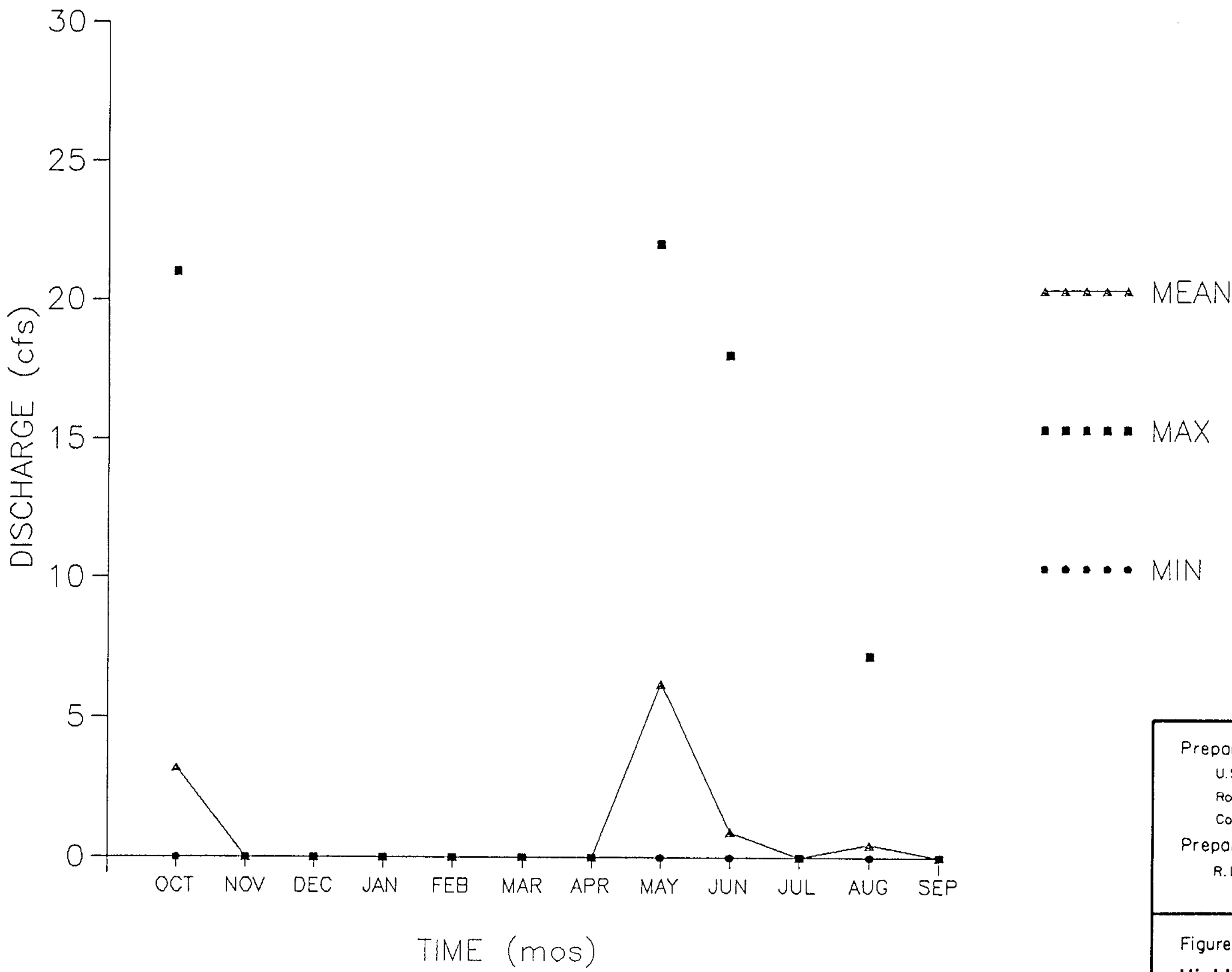

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Figure **4.1-33**
Highline Lateral
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY89
CMP SW FY89

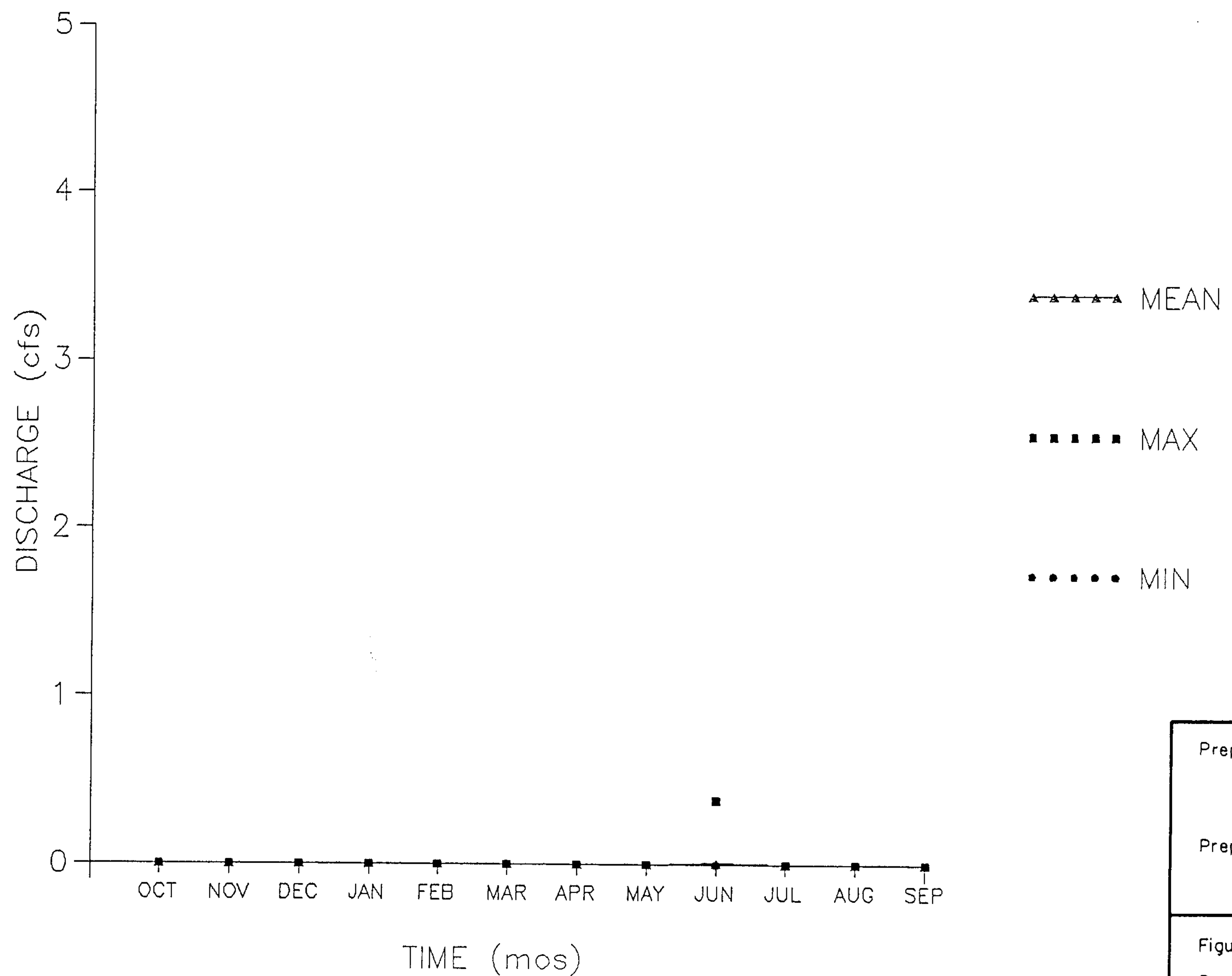

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Figure **4.1-34**

South Plants Ditch
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY89
CMP SW FY89

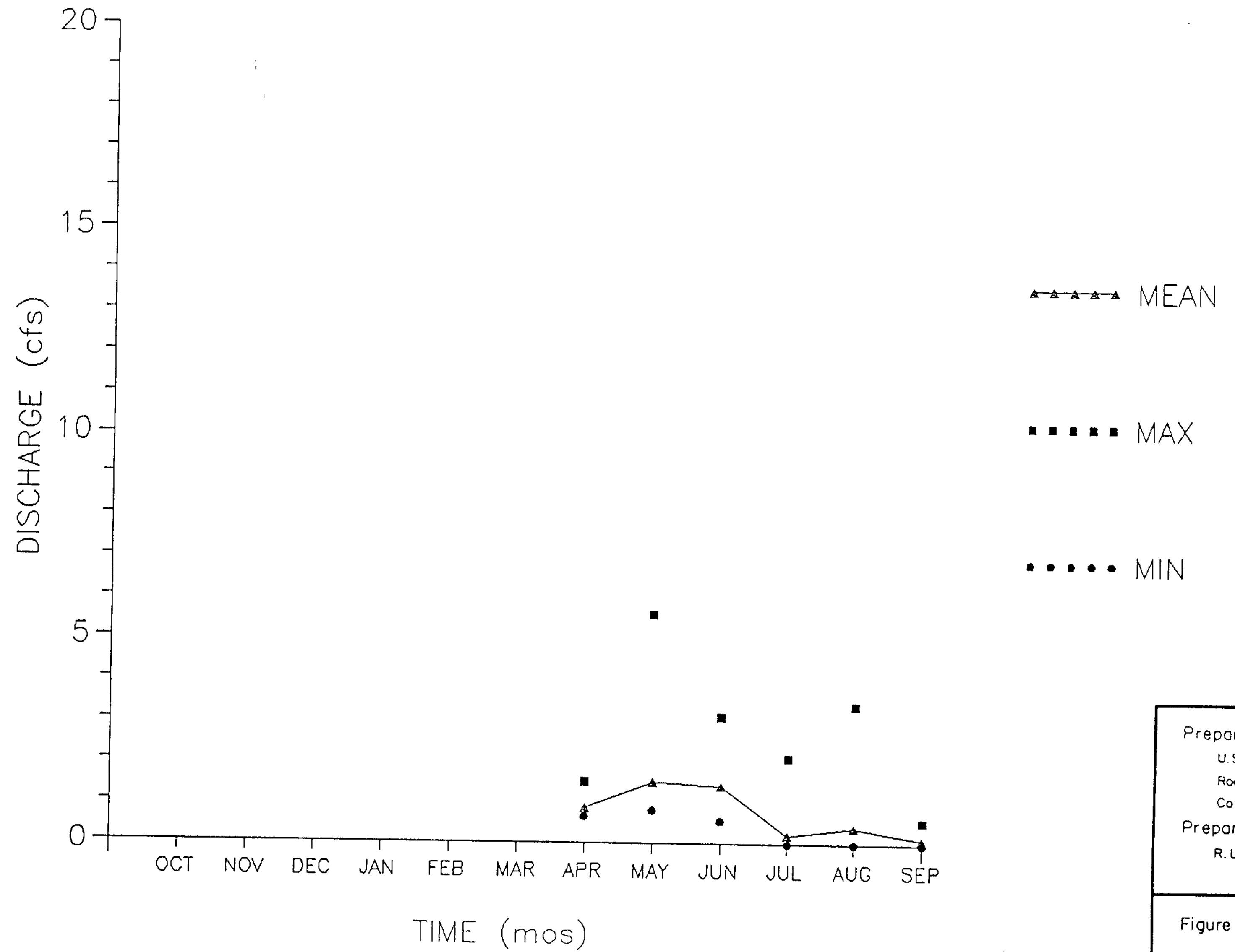

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Figure **4.1-35**

South First Creek
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY89
CMP SW FY89

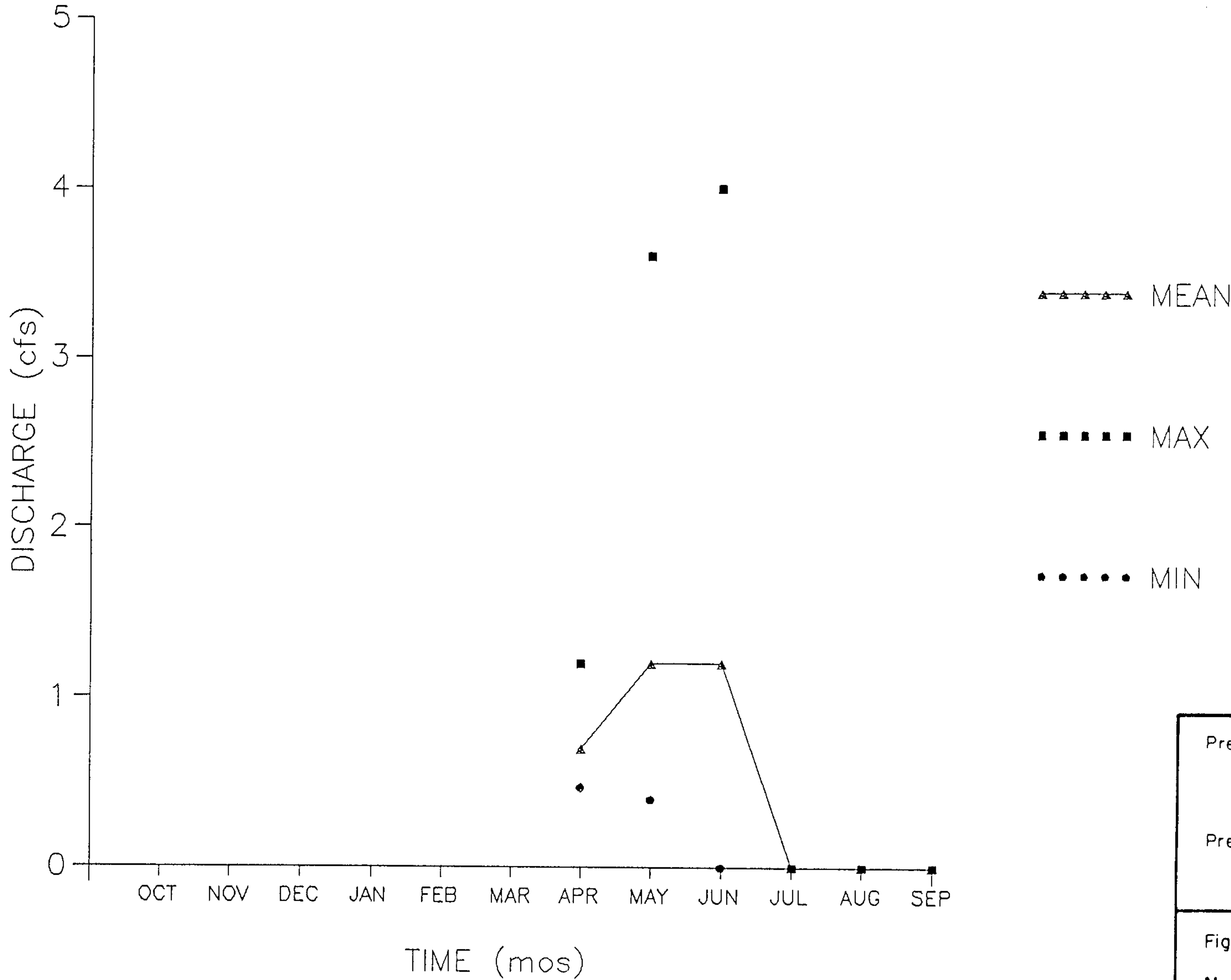

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Figure **4.1-36**

North First Creek
Mean Monthly, Maximum Daily and Minimum Daily Discharge WY89

CMP SW FY89

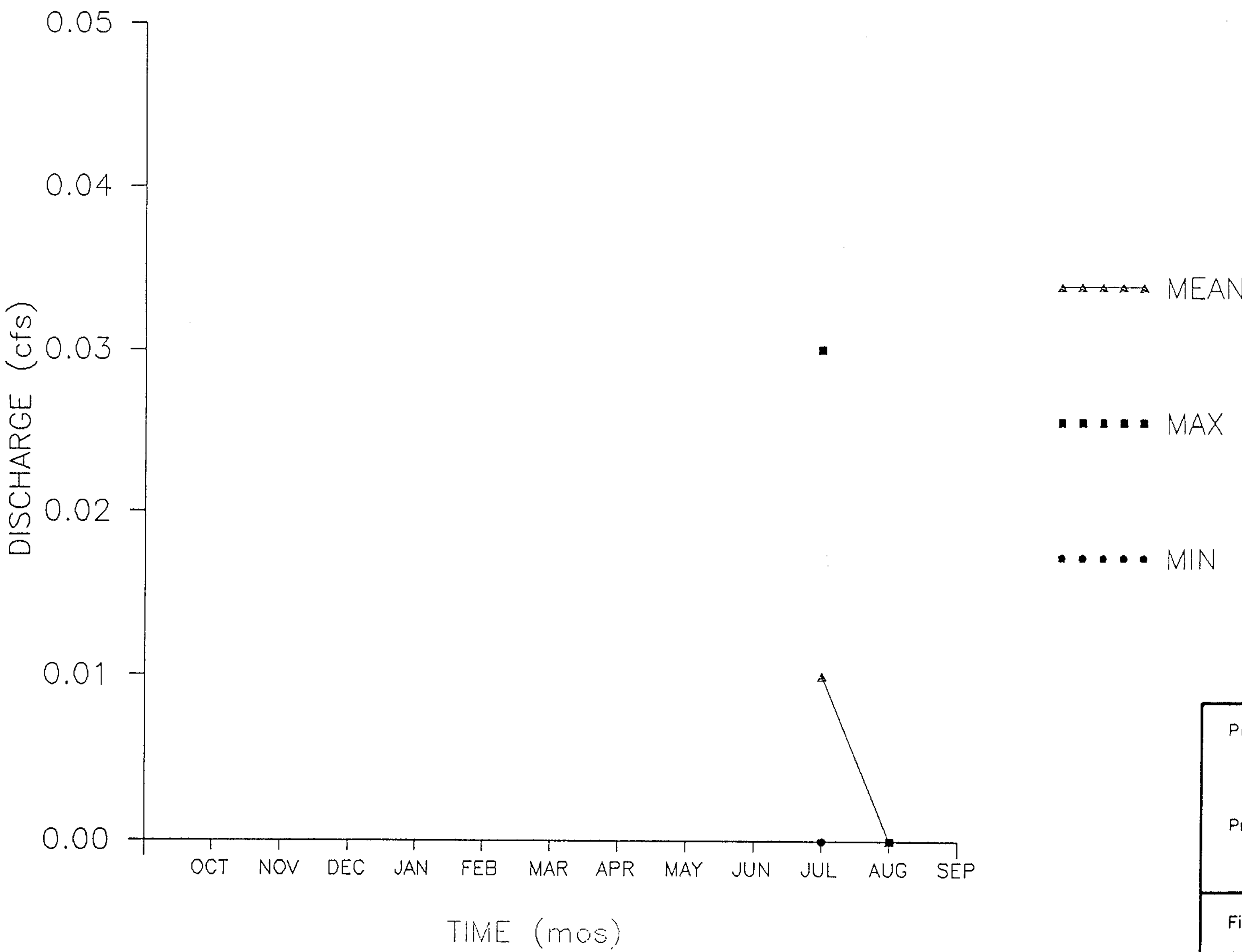

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Figure **4.1-37**

First Creek Off-Post
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY89
CMP SW FY89

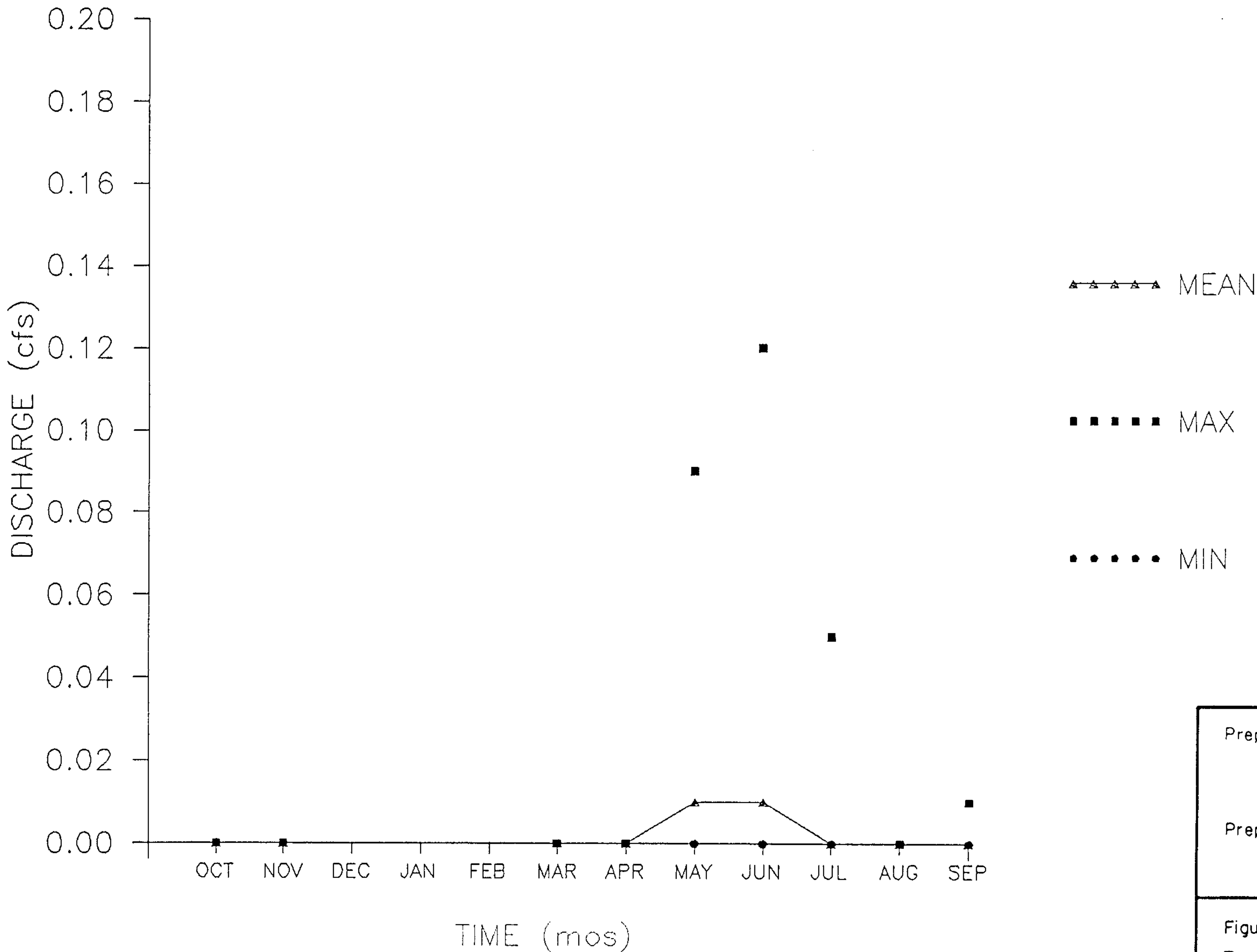

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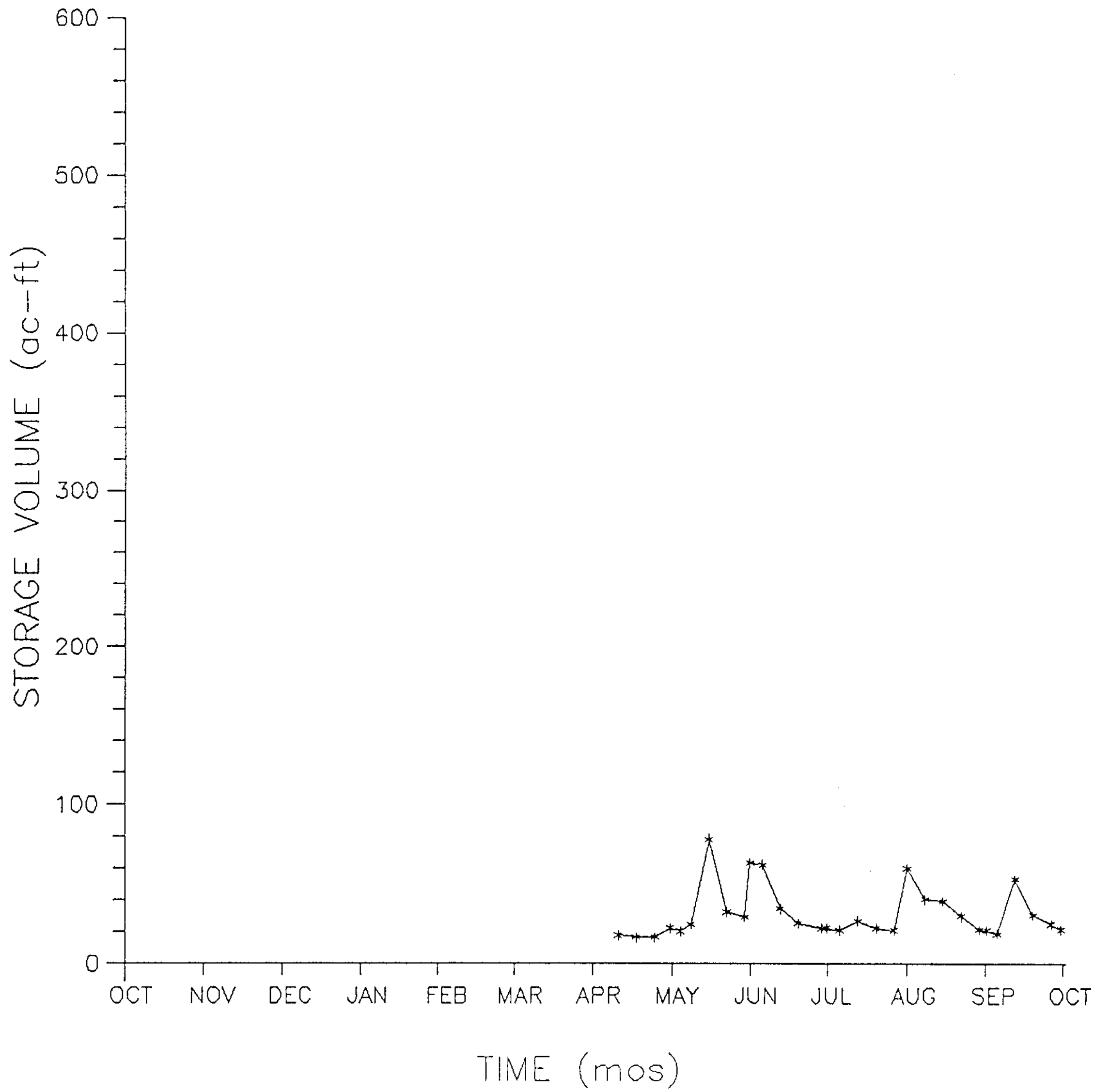
Figure **4.1-38**
Basin A
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY89

CMP SW FY89



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Prepared by:
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Figure **4.1-39**

Havana Pond
Storage Volume WY89

CMP SW FY89

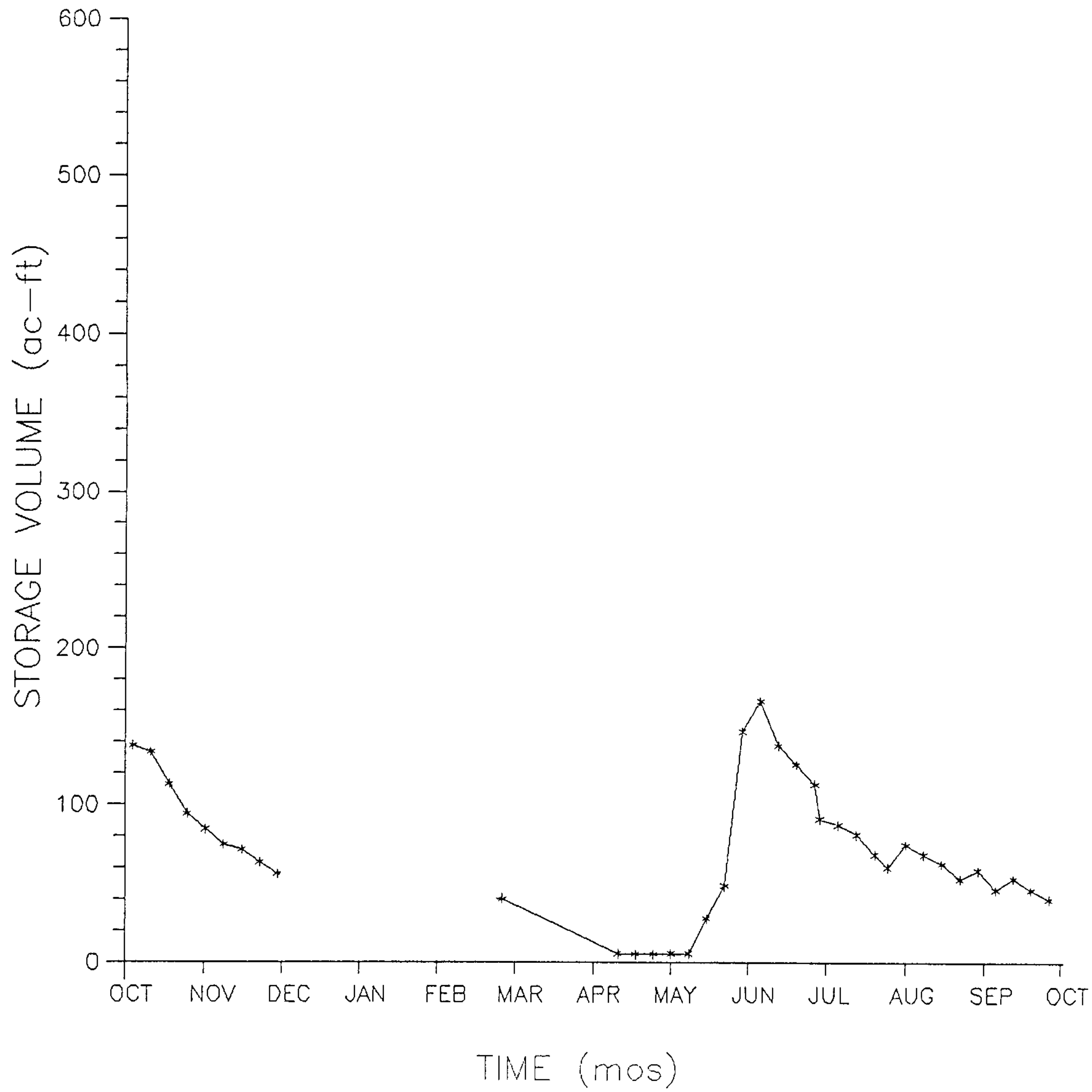

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Figure **4.1-40**

Upper Derby Lake
Storage Volume WY89

CMP SW FY89

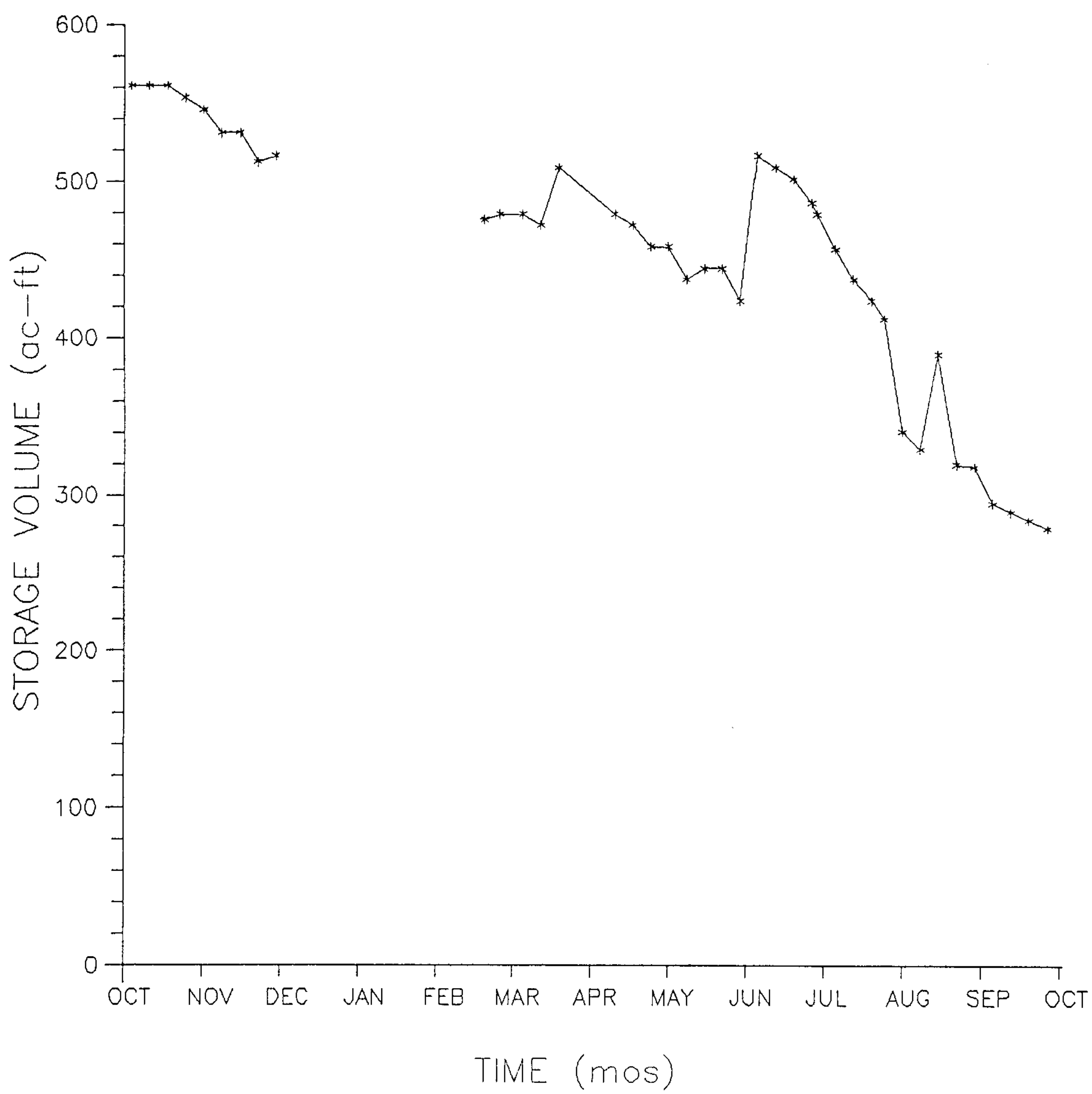

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Figure **4.1-41**

Lower Derby Lake

Storage Volume WY89

CMP SW FY89

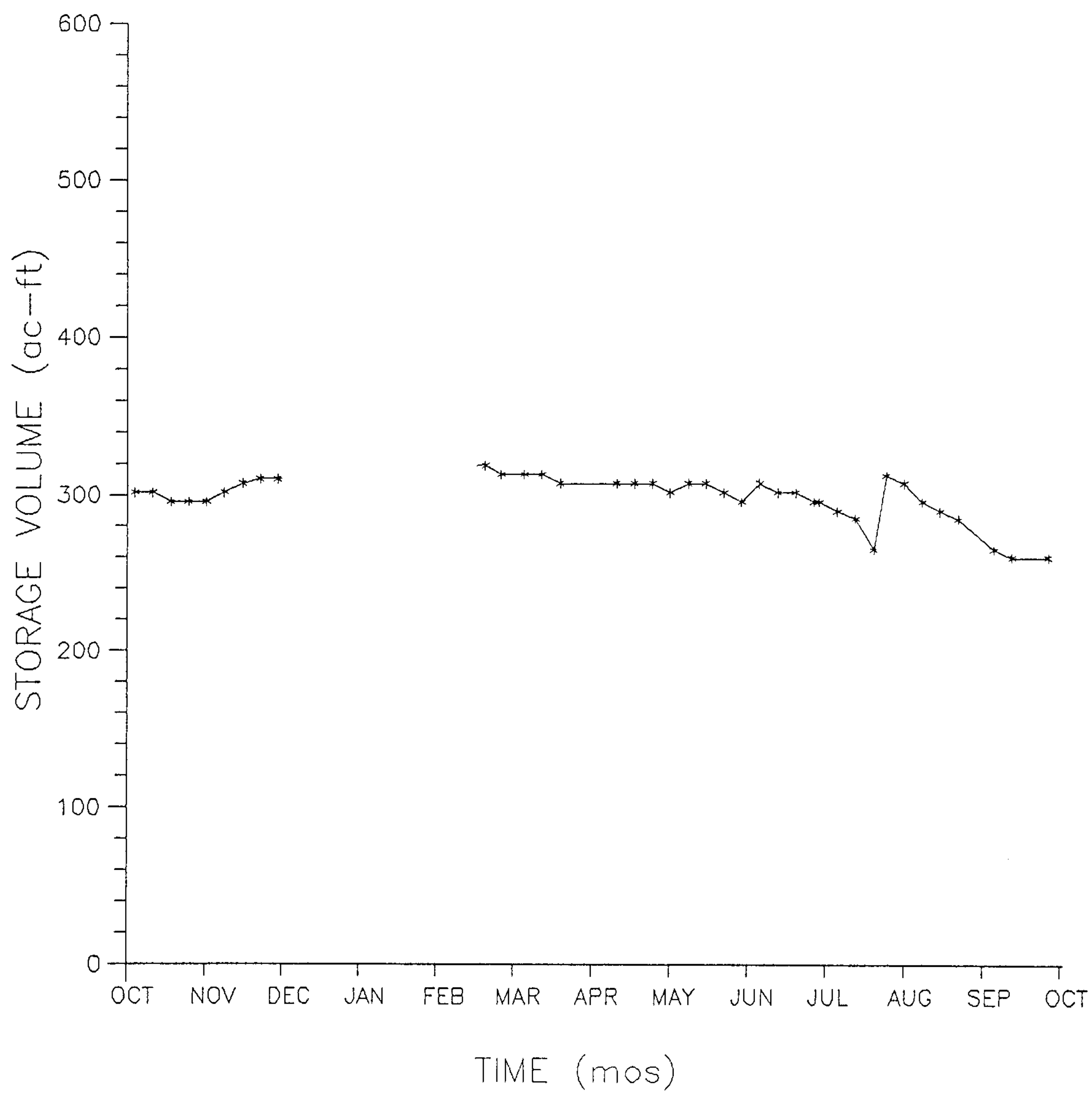

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Figure **4.1-42**

Ladora Lake
Storage Volume WY89

CMP SW FY89

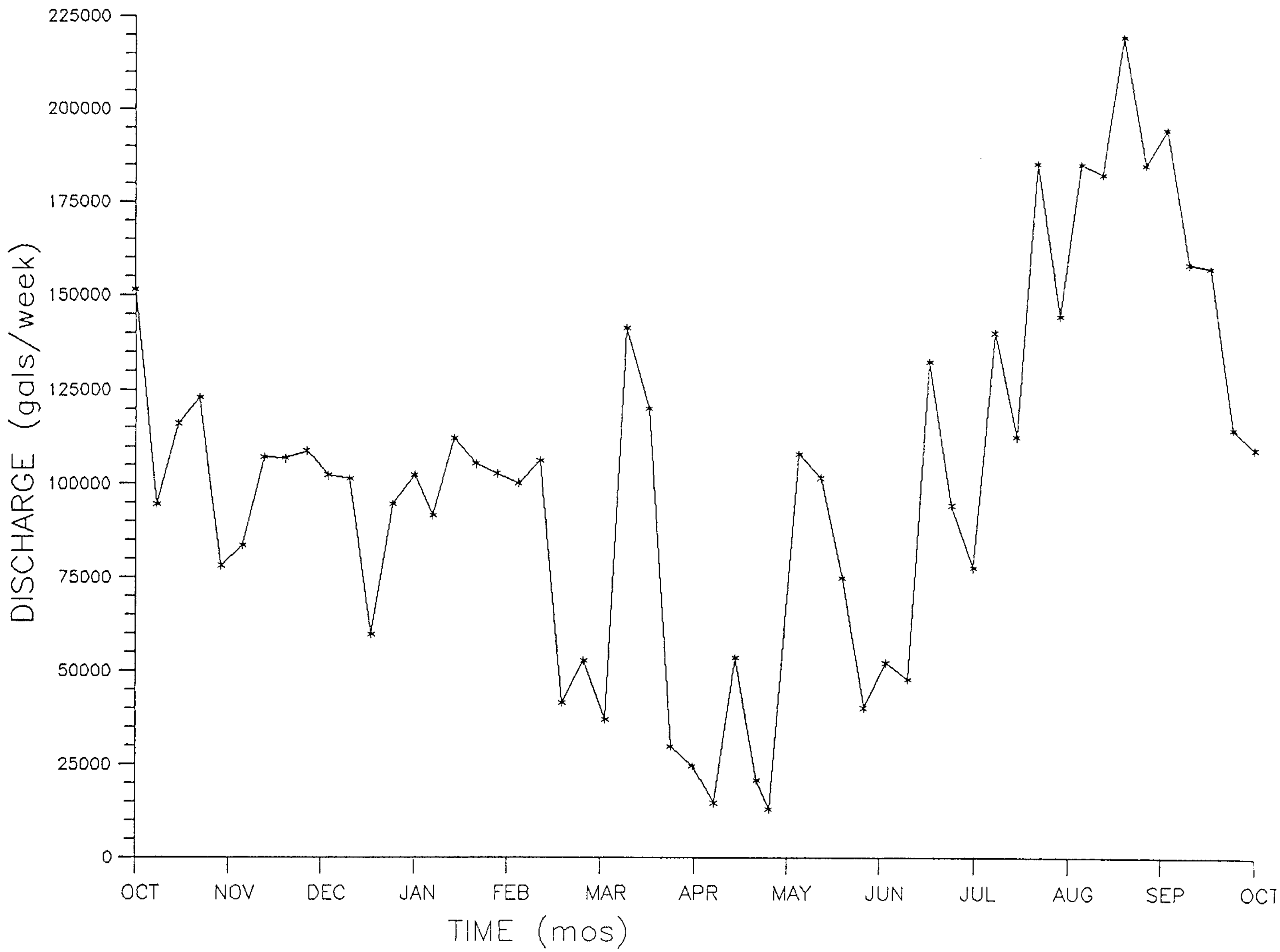

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Figure **4.1-43**

Sewage Treatment Plant Discharge WY89

CMP SW FY89

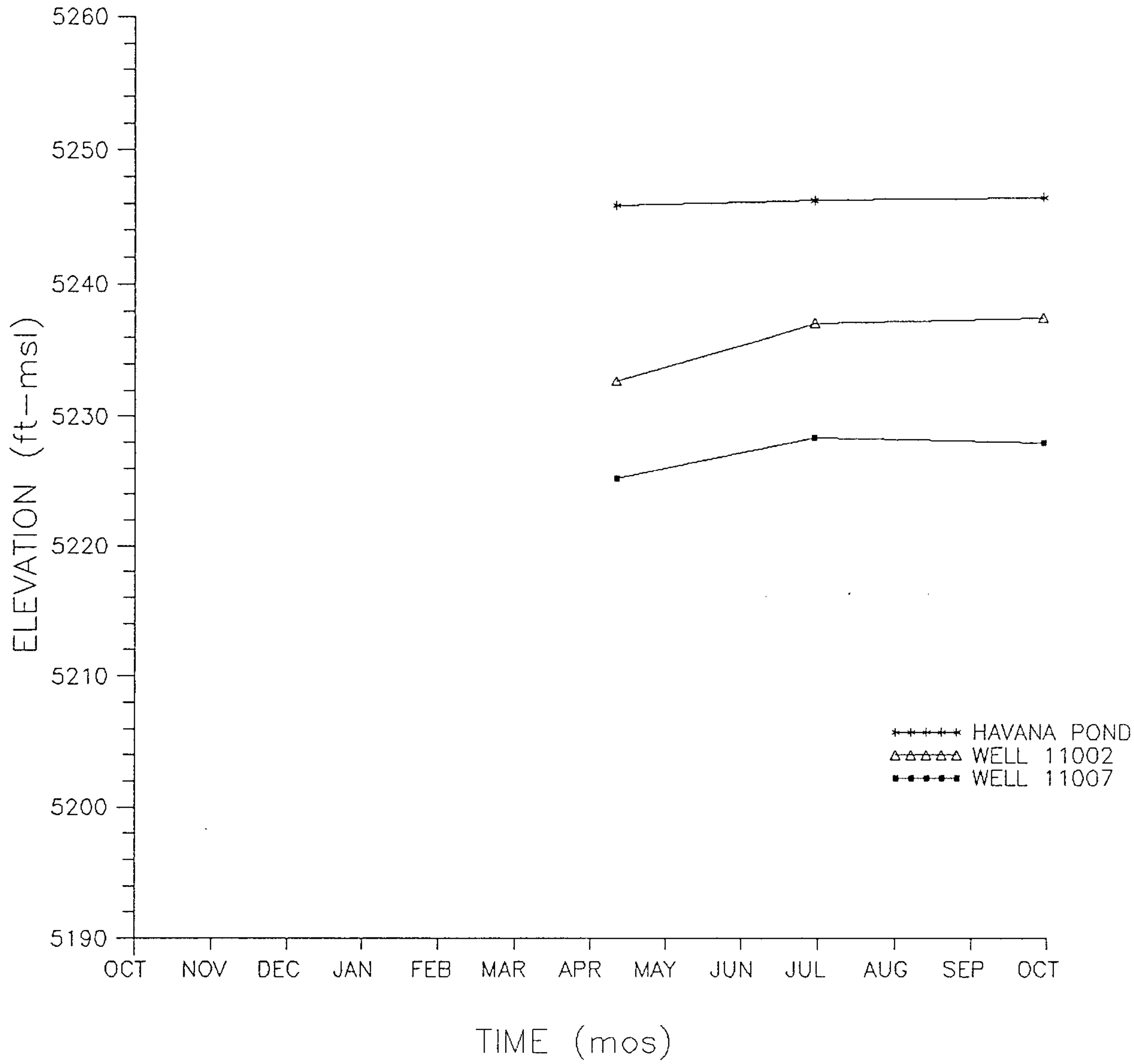

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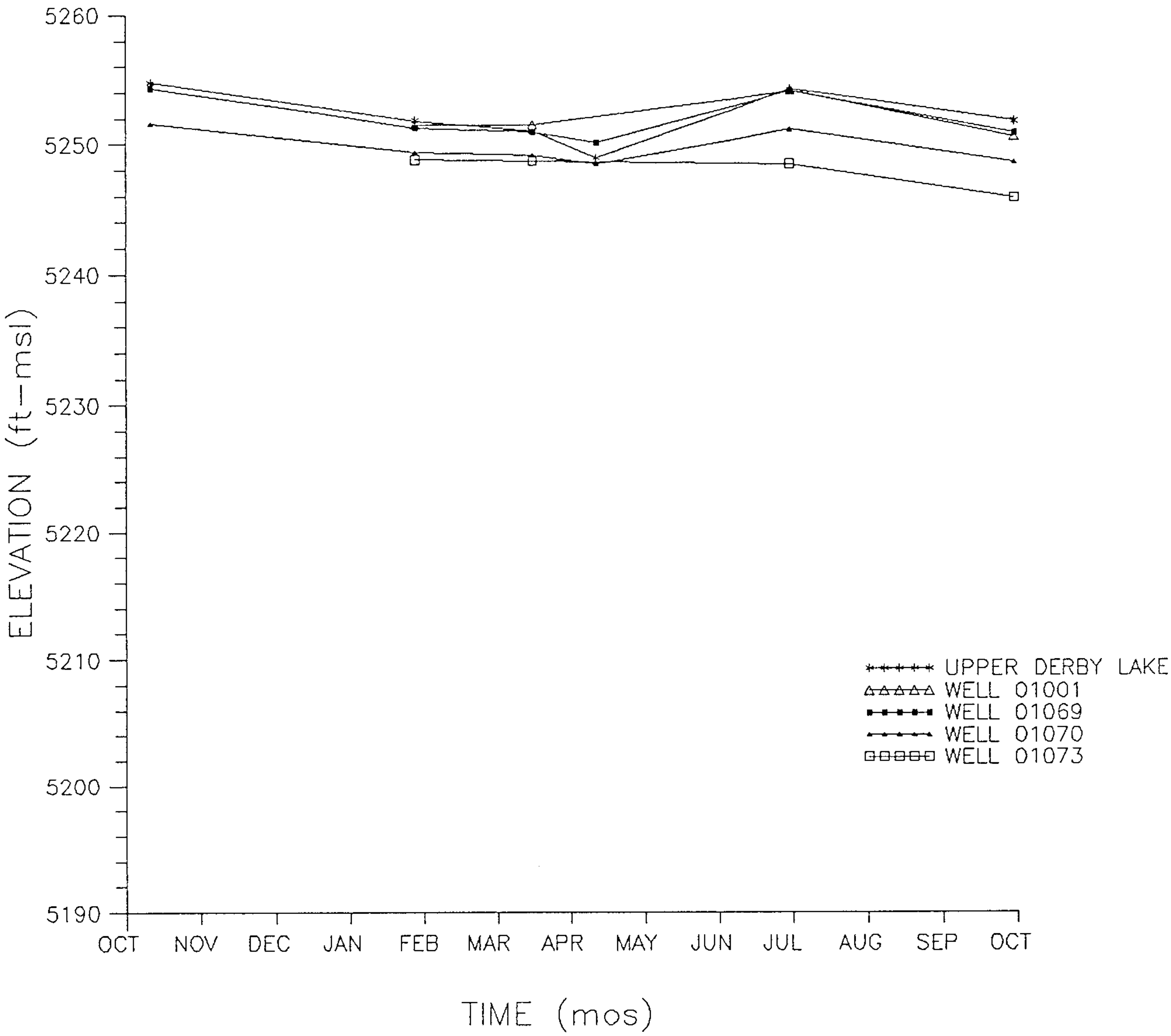
Figure **4.4-1**

Havana Pond and Adjacent Wells WY89 Water Elevations

CMP SW FY89



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Commerce City, Colorado

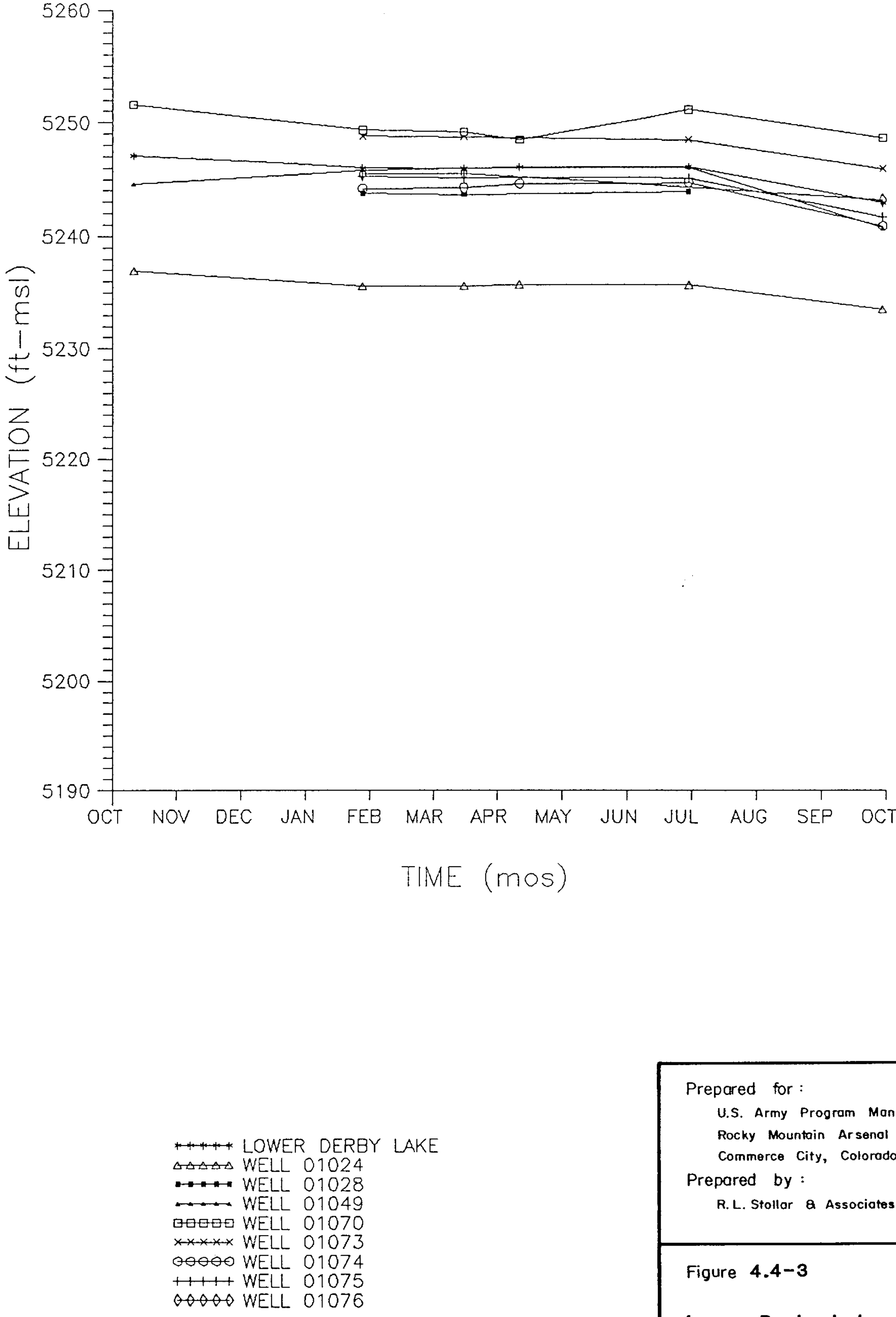
Prepared by:

R.L. Stollar & Associates, Inc.

Figure 4.4-2

Upper Derby Lake and Adjacent Wells WY89 Water Elevations

CMP SW FY89

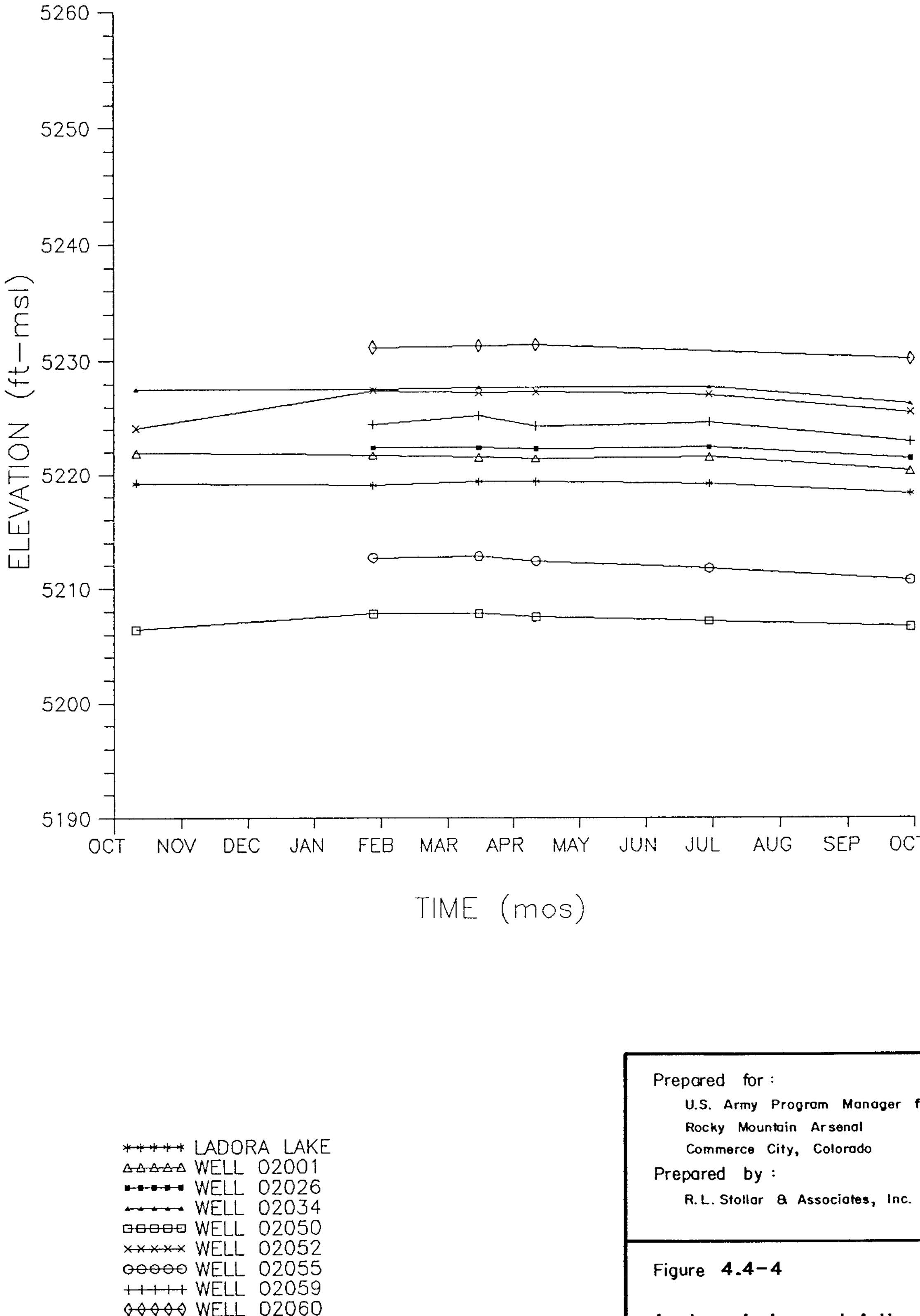


Prepared for :
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R. L. Stollar & Associates, Inc.

Figure 4.4-3

Lower Derby Lake and Adjacent Wells WY89 Water Elevations

CMP SW FY89



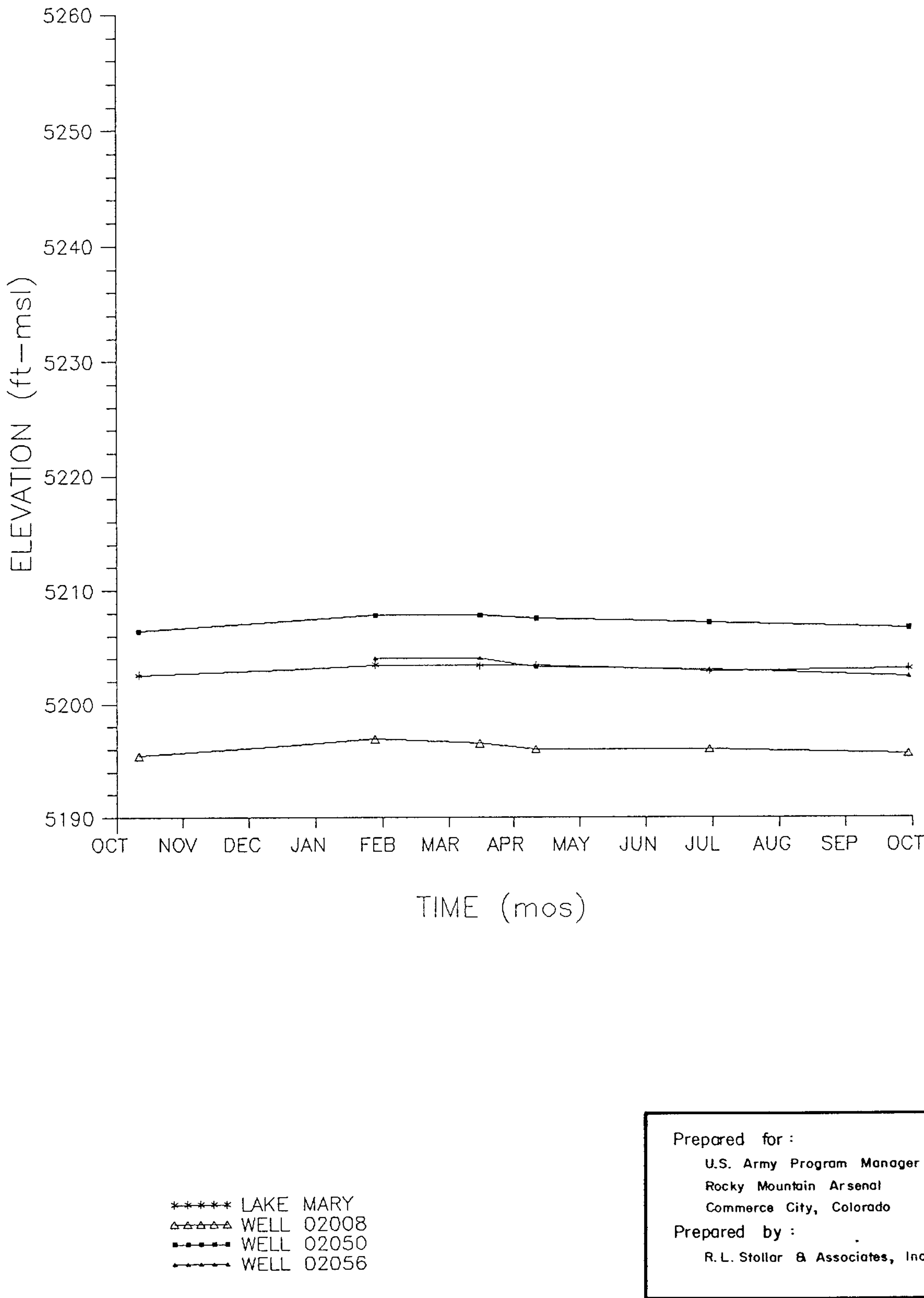
Prepared for :
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :
R.L. Stollar & Associates, Inc.

Figure 4.4-4

Ladora Lake and Adjacent Wells WY89 Water Elevations

CMP SW FY89



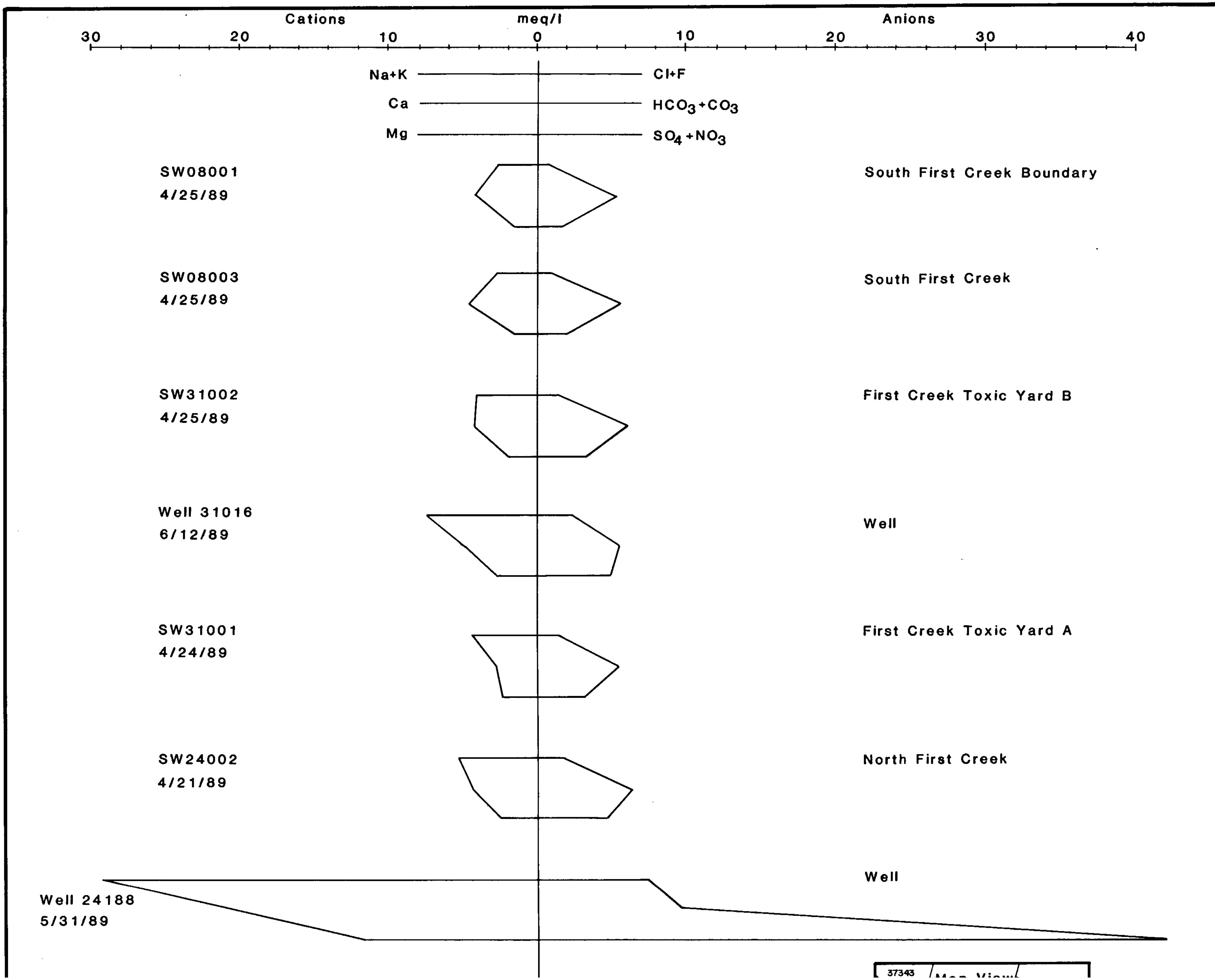
Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.

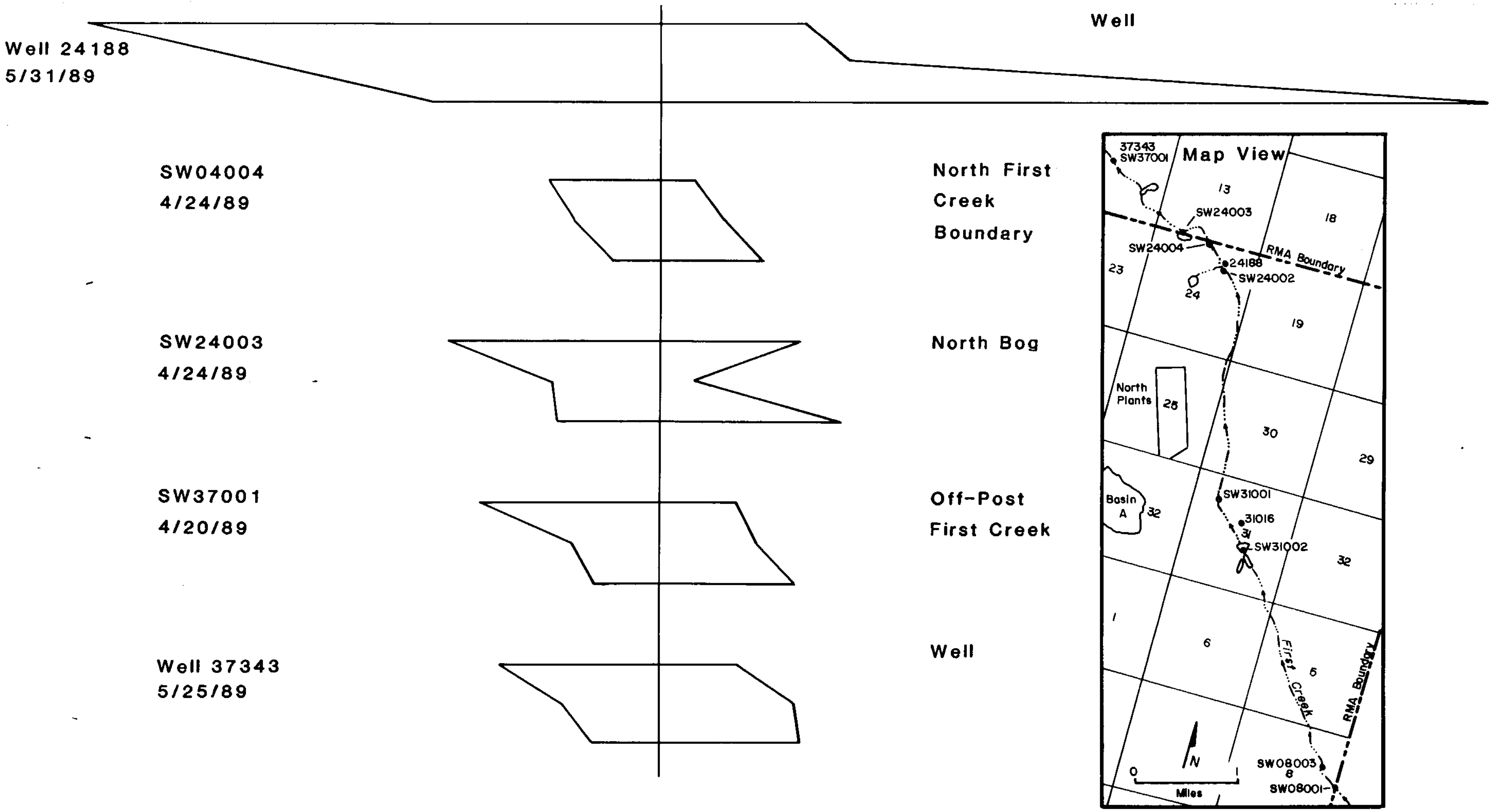
Figure **4.4-5**

Lake Mary and Adjacent Wells WY89 Water Elevations

CMP SW FY89



Cations
meq/l
Anions
30
20
10
0
10
20
30
40
Na+K
Ca
Mg
Cl+F
HCO3+CO3
SO4+NO3
SW08001
4/25/89
South First Creek Boundary
SW08003
4/25/89
South First Creek
SW31002
4/25/89
First Creek Toxic Yard B
Well 31016
6/12/89
Well
SW31001
4/24/89
First Creek Toxic Yard A
SW24002
4/21/89
North First Creek
Well 24188
5/31/89
Well
37343



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

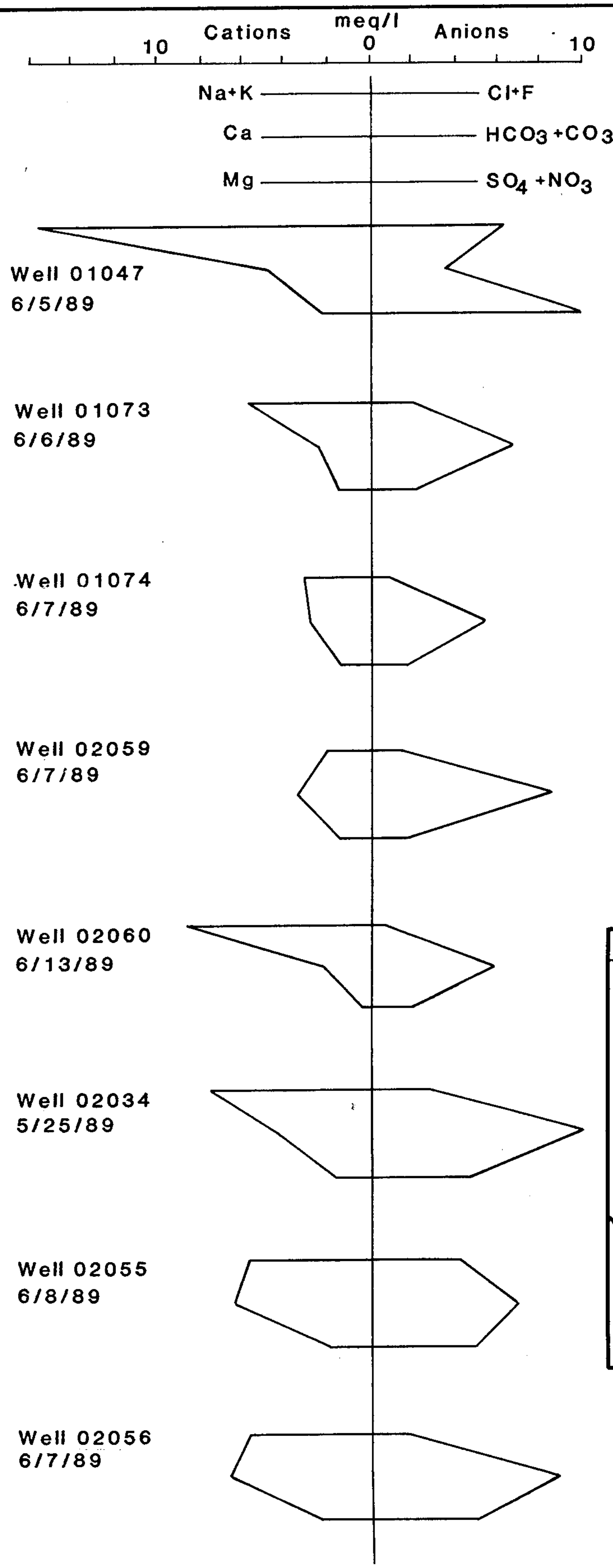
Prepared by :

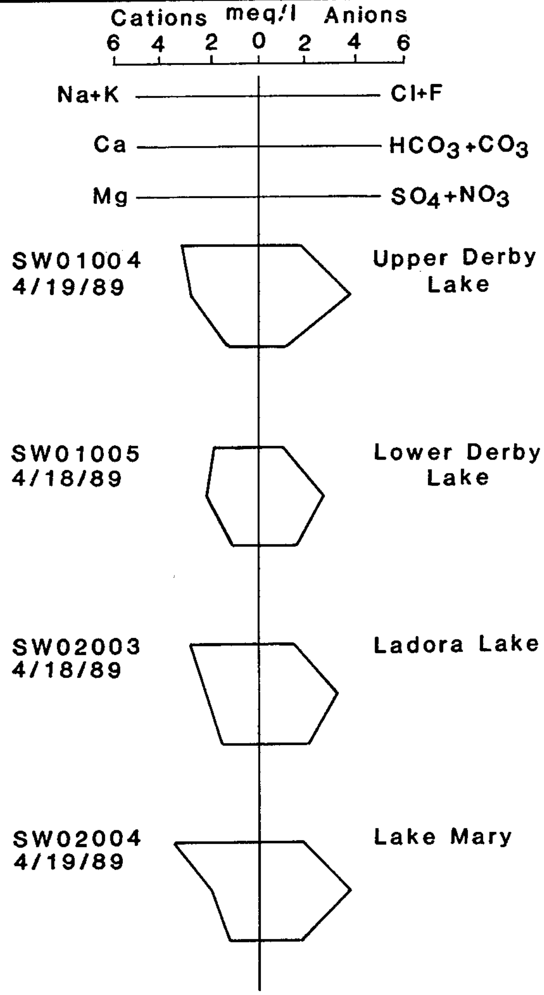
R.L. Stollar & Associates, Inc.
Harding Lawson Associates

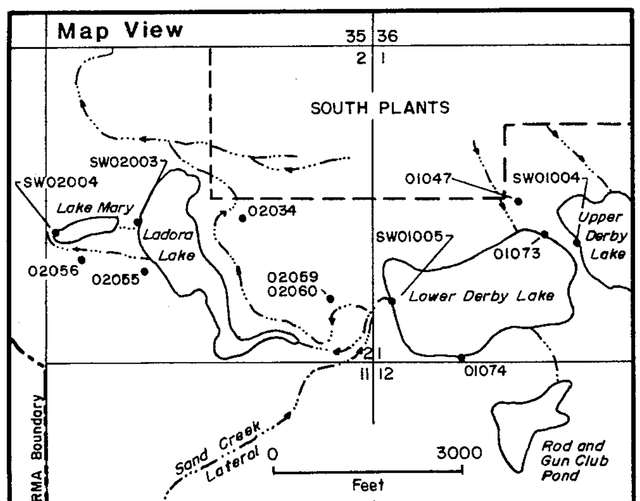
Figure 4.4-6

Surface-Water and Ground-Water Stiff Diagrams for the First Creek Drainage

CMP SW FY89







Prepared for:

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Rocky Mountain Arsenal
Commerce City, Colorado

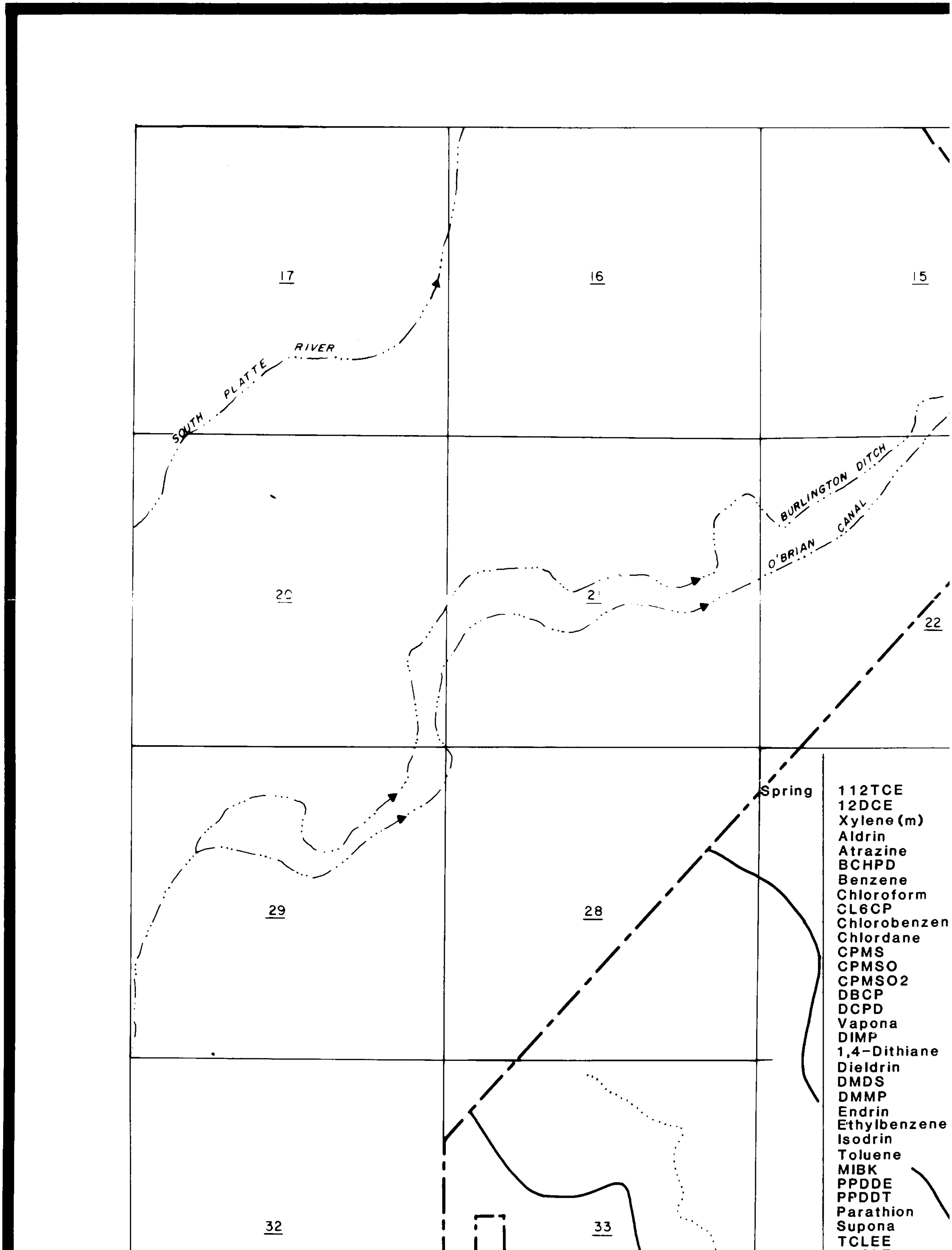
Prepared by:

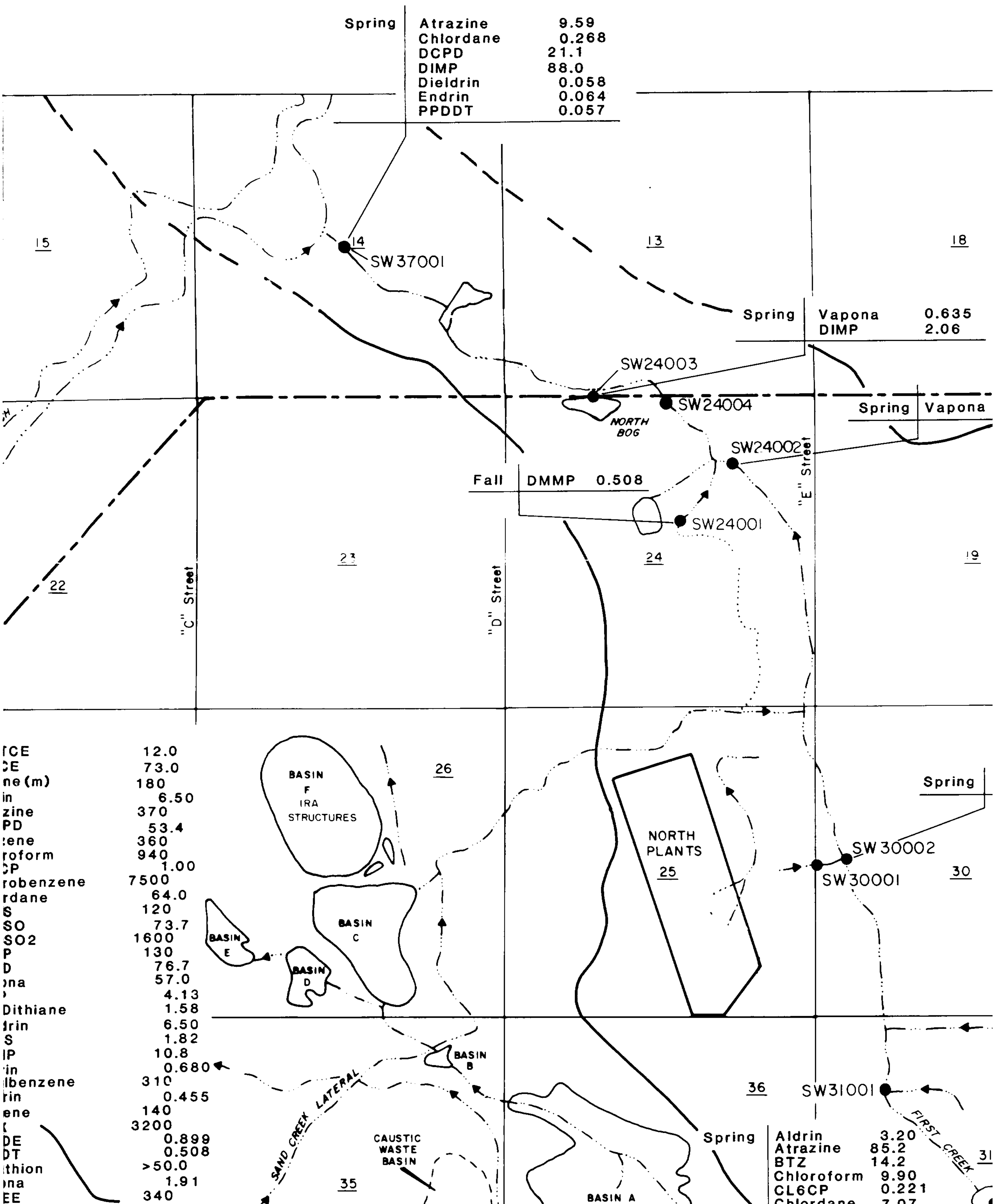
R.L. Stollar & Associates, Inc.

Figure **4.4-7**

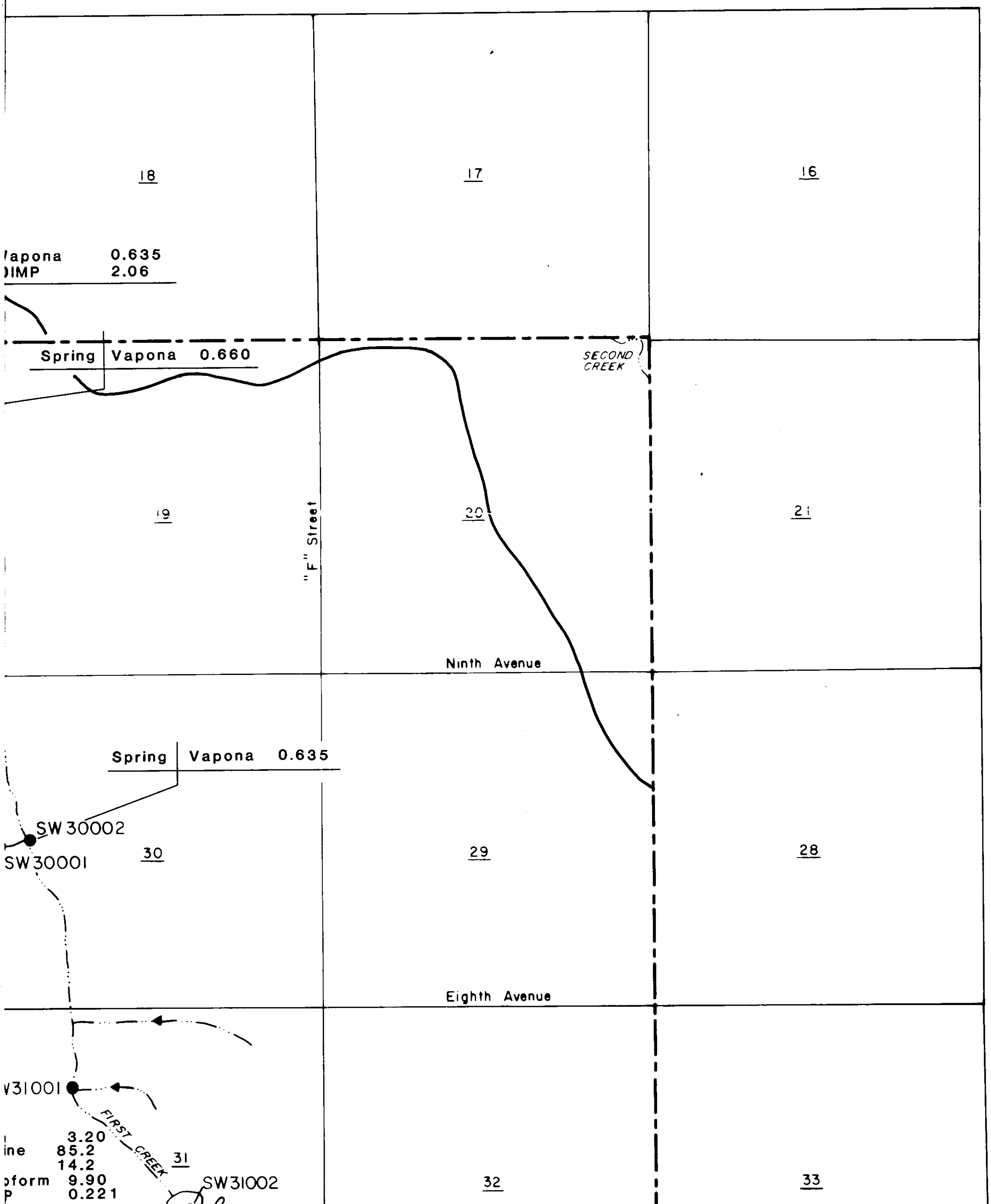
Surface-Water and Ground-Water Stiff Diagrams for the South Plants Lakes Area

CMP SW FY89

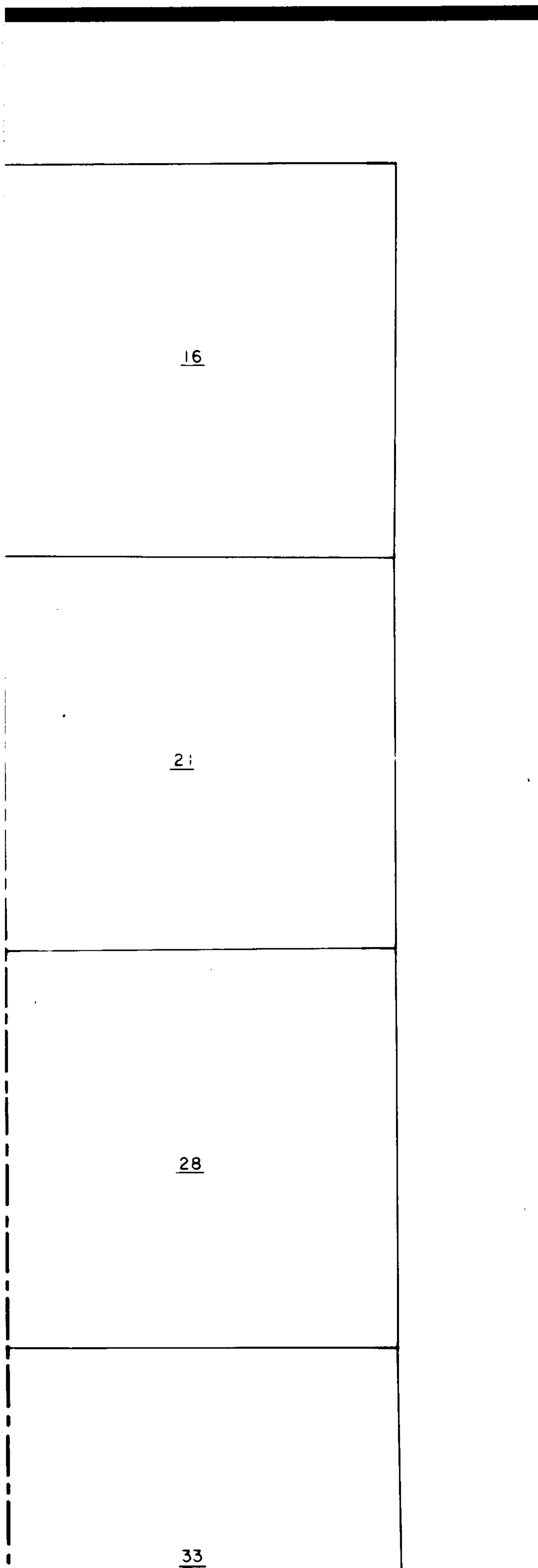

17
16
15
SOUTH PLATTE RIVER
BURLINGTON DITCH
O'BRIAN CANAL
20
21
22
29
28
32
33
Spring
112TCE
12DCE
Xylene (m)
Aldrin
Atrazine
BCHPD
Benzene
Chloroform
CL6CP
Chlorobenzen
Chlordane
CPMS
CPMSO
CPMSO2
DBCP
DCPD
Vapona
DIMP
1,4-Dithiane
Dieldrin
DMDS
DMMP
Endrin
Ethylbenzene
Isodrin
Toluene
MIBK
PPDDE
PPDDT
Parathion
Supona
TCLEE



Spring
Atrazine 9.59
Chlordane 0.268
DCPD 21.1
DIMP 88.0
Dieldrin 0.058
Endrin 0.064
PPDDT 0.057
15
14
SW37001
13
18
Spring
Vapona 0.635
DIMP 2.06
SW24003
SW24004
NORTH BOG
Spring
Vapona
SW24002
"E" Street
Fall
DMMP 0.508
SW24001
22
23
24
19
"C" Street
"D" Street
ΓCE 12.0
:E 73.0
ne (m) 180
in 6.50
zine 370
PD 53.4
:ene 360
roform 940
:P 1.00
robenzene 7500
rdane 64.0
S 120
SO 73.7
SO2 1600
P 130
D 76.7
ona 57.0
4.13
Dithiane 1.58
drin 6.50
S 1.82
IP 10.8
in 0.680
lbenzene 310
rin 0.455
ene 140
3200
DE 0.899
DT 0.508
thion >50.0
ona 1.91
EE 340
BASIN F
IRA STRUCTURES
26
NORTH PLANTS
25
Spring
SW30002
SW30001
30
BASIN C
BASIN E
BASIN D
BASIN B
SAND CREEK LATERAL
CAUSTIC WASTE BASIN
35
BASIN A
36
SW31001
FIRST CREEK
31
Spring
Aldrin 3.20
Atrazine 85.2
BTZ 14.2
Chloroform 9.90
CL6CP 0.221



18
17
16
/apona 0.635
)IMP 2.06
Spring
Vapona 0.660
SECOND CREEK
19
"F" Street
20
21
Ninth Avenue
Spring
Vapona 0.635
SW30002
SW30001
30
29
28
Eighth Avenue
V31001
FIRST CREEK
3.20
ine 85.2
14.2
oform 9.90
P 0.221
31
SW31002
32
33



Legend

20	Section Number
	Lake, Pond or Basin
	Stream or Ditch with Flow Direction
	Abandoned Stream or Ditch
SW24001	Surface Water Sample Location
	Arsenal Boundary

Sampling Summary

Spring (4/18-5/18/89) 26 Sites

SW01001	SW08003	SW24002
SW01002	SW11001	SW24003
SW01004	SW11002	SW24004
SW01005	SW11003	SW30002
SW02003	SW12001	SW31001
SW02004	SW12003	SW31002
SW02006	SW12004	SW36001
SW07001	SW12005	SW37001
SW08001	SW24001	

Storm Events 7 Sites

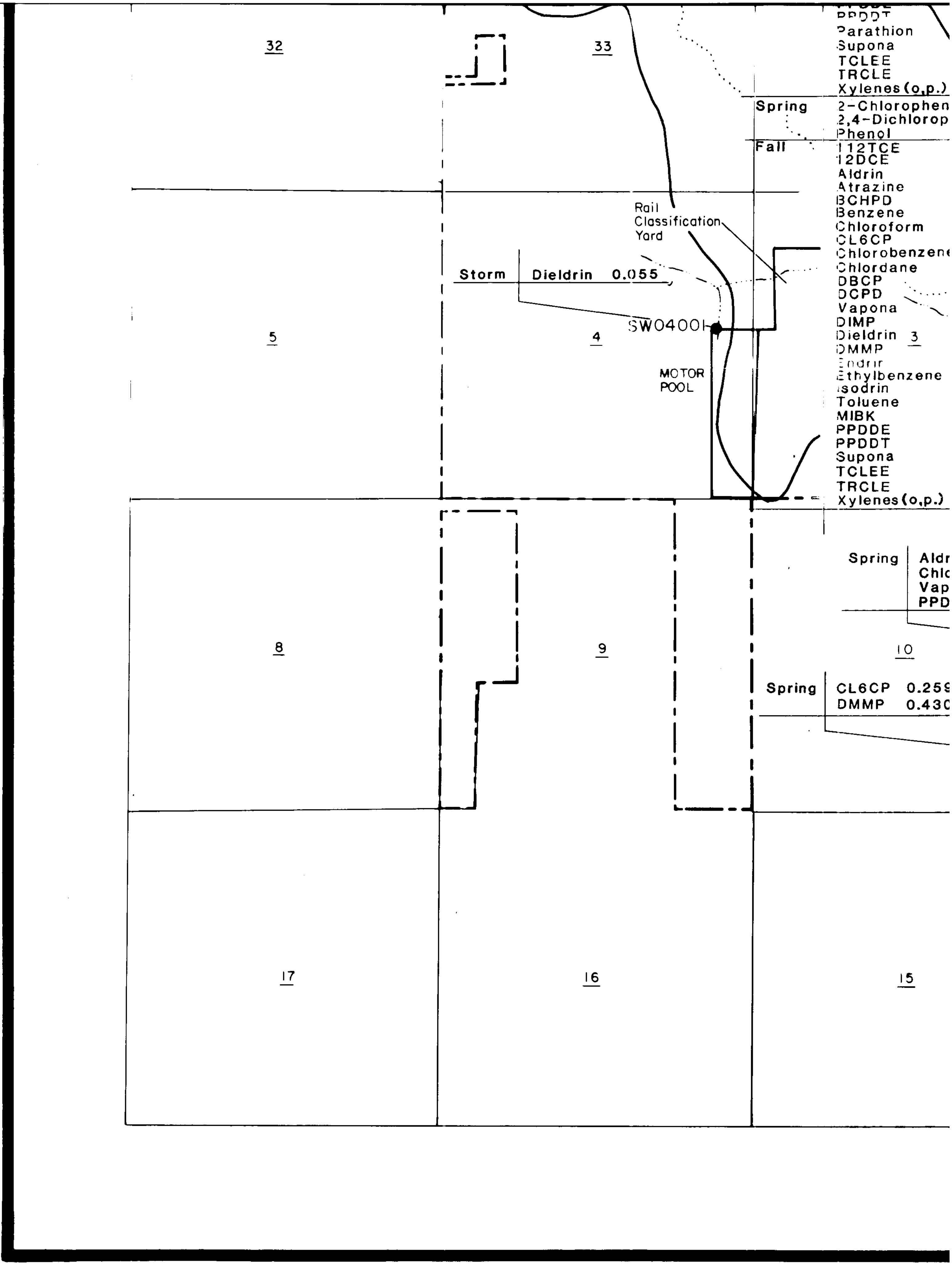
SW04001	SW11002	SW24002
SW08003	SW12002	
SW11001	SW12005	

Fall (9/25-9/28/89) 12 Sites

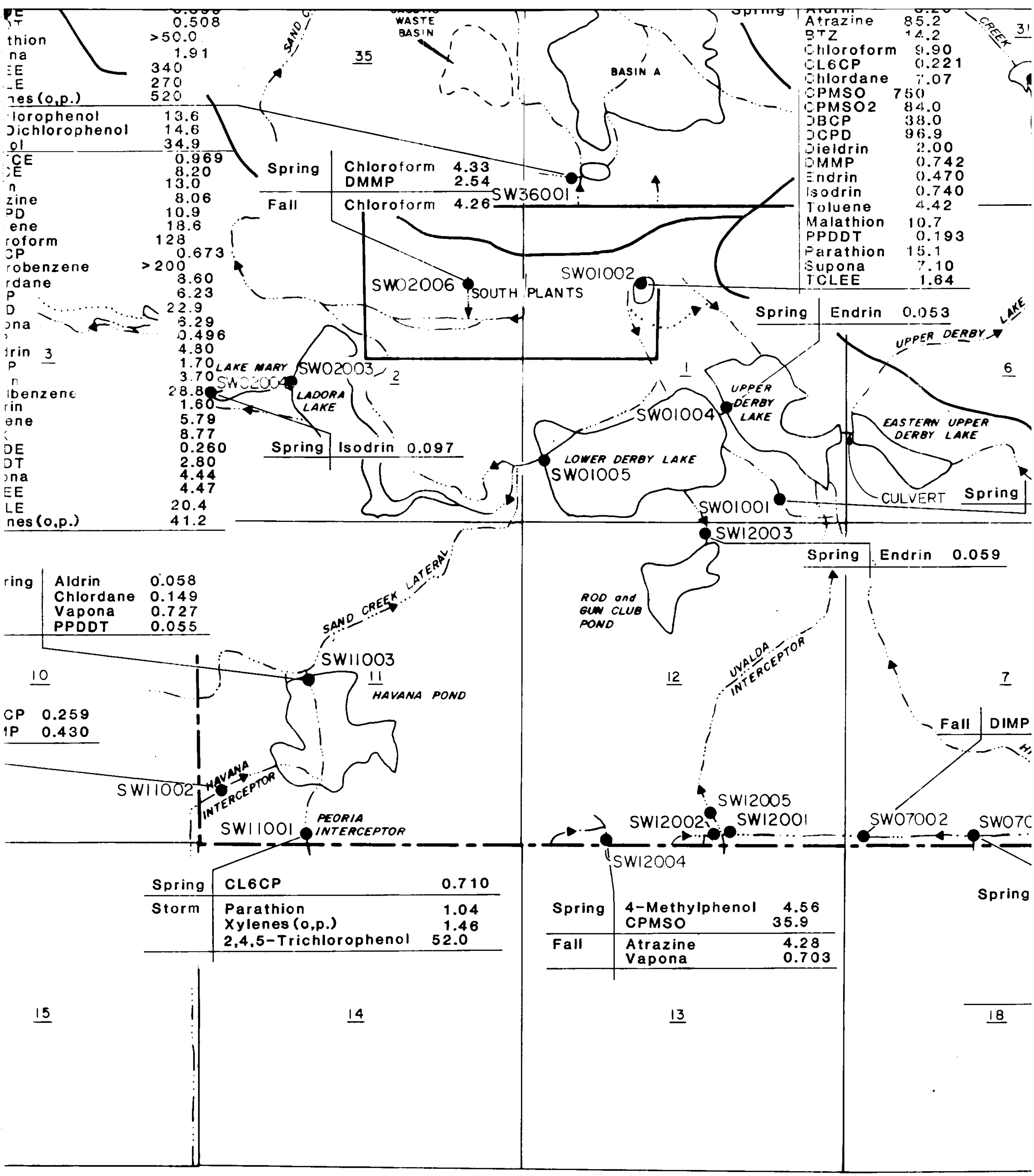
SW01001	SW08003	SW12004
SW02006	SW11001	SW12005
SW07001	SW11002	SW24001
SW07002	SW12001	SW36001

Acronyms

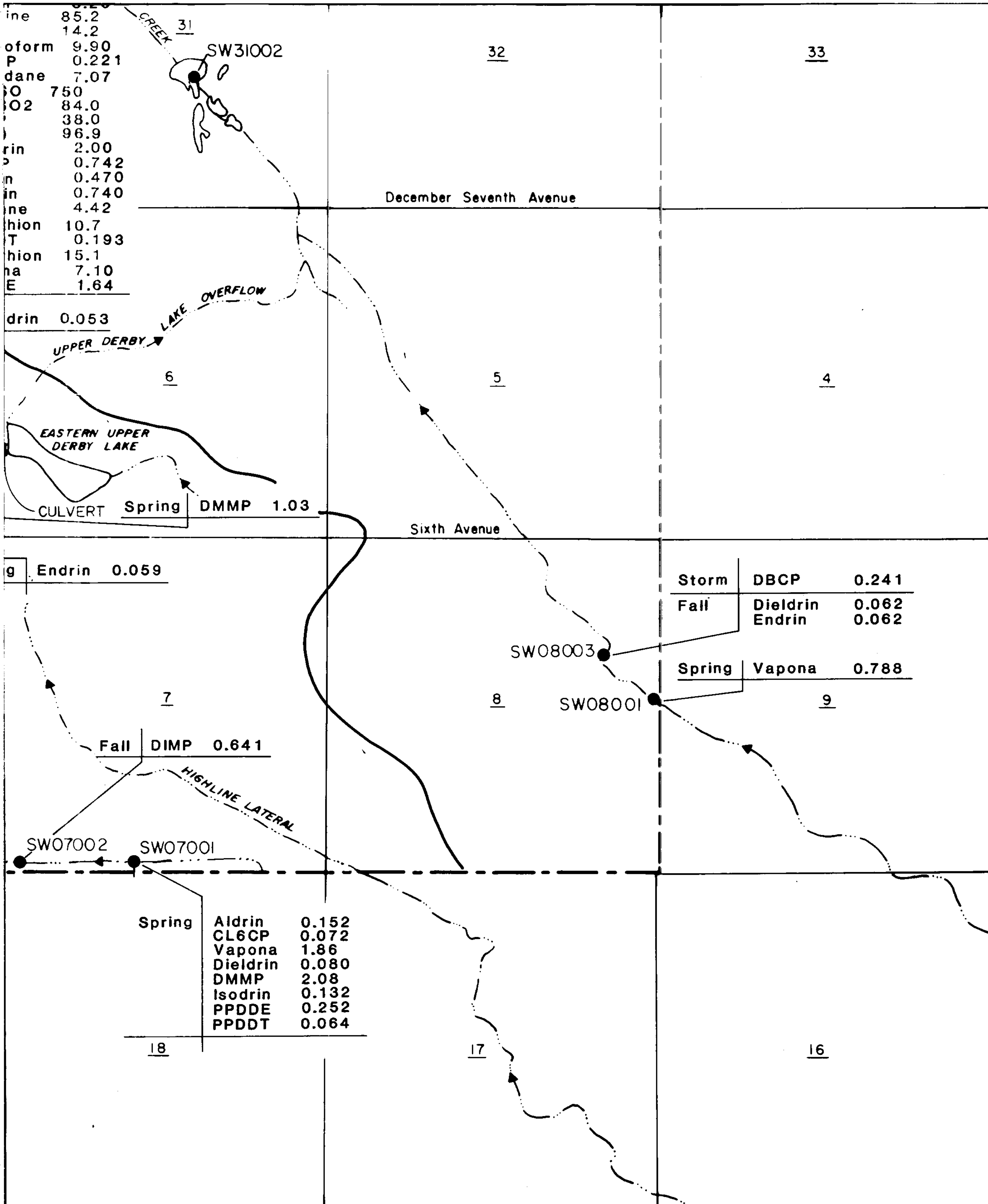
112TCE	1,1,2-Trichloroethane
12DCE	1,2-Dichloroethene
BCHPD	Bicycloheptadiene
BTZ	Benzothiazole
CL6CP	Hexachlorocyclopentadiene
CPMS	P-Chlorophenylmethylsulfide
CPMSO	P-Chlorophenylmethylsulfoxide
CPMSO2	P-Chlorophenylmethylsulfone

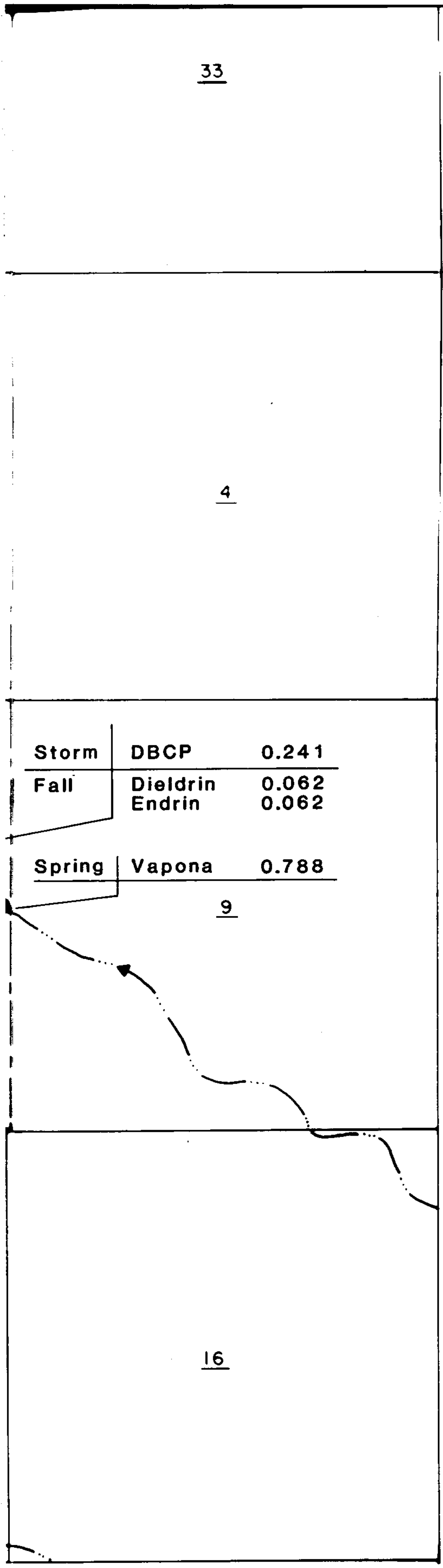


32
33
PPDDT
Parathion
Supona
TCLEE
TRCLE
Xylenes (o,p.)
Spring
2-Chlorophen
2,4-Dichlorop
Phenol
Fall
112TCE
12DCE
Aldrin
Atrazine
BCHPD
Benzene
Chloroform
CL6CP
Chlorobenzene
Chlordane
DBCP
DCPD
Vapona
DIMP
Dieldrin
DMMP
Endrin
Ethylbenzene
Isodrin
Toluene
MIBK
PPDDE
PPDDT
Supona
TCLEE
TRCLE
Xylenes (o,p.)
Rail
Classification
Yard
Storm
Dieldrin 0.055
SW04001
MOTOR
POOL
5
4
3
Spring
Aldr
Chlo
Vap
PPD
8
9
10
Spring
CL6CP 0.259
DMMP 0.430
17
16
15



0.508
thion >50.0
na 1.91
EE 340
LE 270
nes (o,p.) 520
lorophenol 13.6
Dichlorophenol 14.6
ol 34.9
CE 0.969
E 8.20
n 13.0
zine 8.06
PD 10.9
ene 18.6
roform 128
CP 0.673
robenzene >200
rdane 8.60
P 6.23
D 22.9
ona 6.29
0.496
drin 4.80
P 1.70
n 3.70
lbenzene 28.8
rin 1.60
ene 5.79
8.77
DE 0.260
DT 2.80
ona 4.44
EE 4.47
LE 20.4
nes (o,p.) 41.2
WASTE BASIN
35
BASIN A
Atrazine 85.2
BTZ 14.2
Chloroform 9.90
CL6CP 0.221
Chlordane 7.07
CPMSO 750
CPMSO2 84.0
DBCP 38.0
DCPD 96.9
Dieldrin 2.00
DMMP 0.742
Endrin 0.470
Isodrin 0.740
Toluene 4.42
Malathion 10.7
PPDDT 0.193
Parathion 15.1
Supona 7.10
TCLEE 1.64
CREEK
Spring Chloroform 4.33
DMMP 2.54
Fall Chloroform 4.26
SW36001
SW02006
SOUTH PLANTS
SW01002
Spring Endrin 0.053
UPPER DERBY LAKE
6
1
3
LAKE MARY
SW02003
SW02004
2
LADORA LAKE
UPPER DERBY LAKE
SW01004
EASTERN UPPER DERBY LAKE
Spring Isodrin 0.097
LOWER DERBY LAKE
SW01005
CULVERT
Spring
SW01001
SW12003
Spring Endrin 0.059
ring Aldrin 0.058
Chlordane 0.149
Vapona 0.727
PPDDT 0.055
SAND CREEK LATERAL
ROD and GUN CLUB POND
SW11003
10
11
HAVANA POND
12
UVALDA INTERCEPTOR
7
CP 0.259
IP 0.430
Fall DIMP
HAVANA INTERCEPTOR
SW11002
PEORIA INTERCEPTOR
SW11001
SW12005
SW12002
SW12001
SW07002
SW12004
Spring CL6CP 0.710
Storm Parathion 1.04
Xylenes (o,p.) 1.46
2,4,5-Trichlorophenol 52.0
Spring 4-Methylphenol 4.56
CPMSO 35.9
Fall Atrazine 4.28
Vapona 0.703
Spring
15
14
13
18

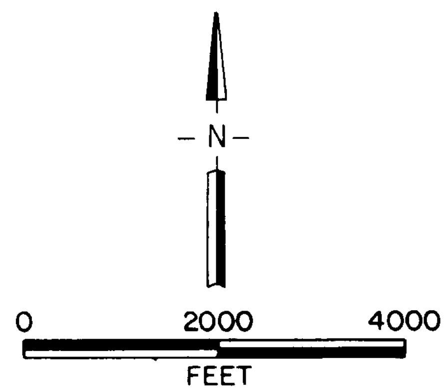

ine 85.2
14.2
oform 9.90
P 0.221
dane 7.07
O 750
O2 84.0
38.0
96.9
rin 2.00
0.742
n 0.470
in 0.740
ne 4.42
hion 10.7
T 0.193
hion 15.1
a 7.10
E 1.64
drin 0.053
CREEK
31
SW31002
32
33
December Seventh Avenue
UPPER DERBY LAKE OVERFLOW
6
5
4
EASTERN UPPER DERBY LAKE
CULVERT
Spring DMMP 1.03
Sixth Avenue
g Endrin 0.059
Storm DBCP 0.241
Fall Dieldrin 0.062
Endrin 0.062
SW08003
Spring Vapona 0.788
SW08001
7
8
9
Fall DIMP 0.641
HIGHLINE LATERAL
SW07002
SW07001
Spring Aldrin 0.152
CL6CP 0.072
Vapona 1.86
Dieldrin 0.080
DMMP 2.08
Isodrin 0.132
PPDDE 0.252
PPDDT 0.064
18
17
16



CPMS	P-Chlorophenylmethylsulfide
CPMSO	P-Chlorophenylmethylsulfoxide
CPMSO2	P-Chlorophenylmethylsulfone
DBCP	Dibromochloropropane
DCPD	Dicyclopentadiene
DIMP	Diisopropylmethylphosphonate
DMMP	Dimethylmethylphosphonate
MIBK	Methylisobutyl Ketone
PPDDE	2,2-Bis(para-chlorophenyl) - 1,1-dichloroethene
PPDDT	2,2-Bis(para-chlorophenyl)- 1,1,1-trichloroethene
TCLEE	Tetrachloroethene
TRCLE	Trichloroethene

All concentrations in µg/l.

Drainage Basin Boundary



Prepared for :

U.S. Army, Program Manager for

Rocky Mountain Arsenal

Commerce City, Colorado

Prepared by :

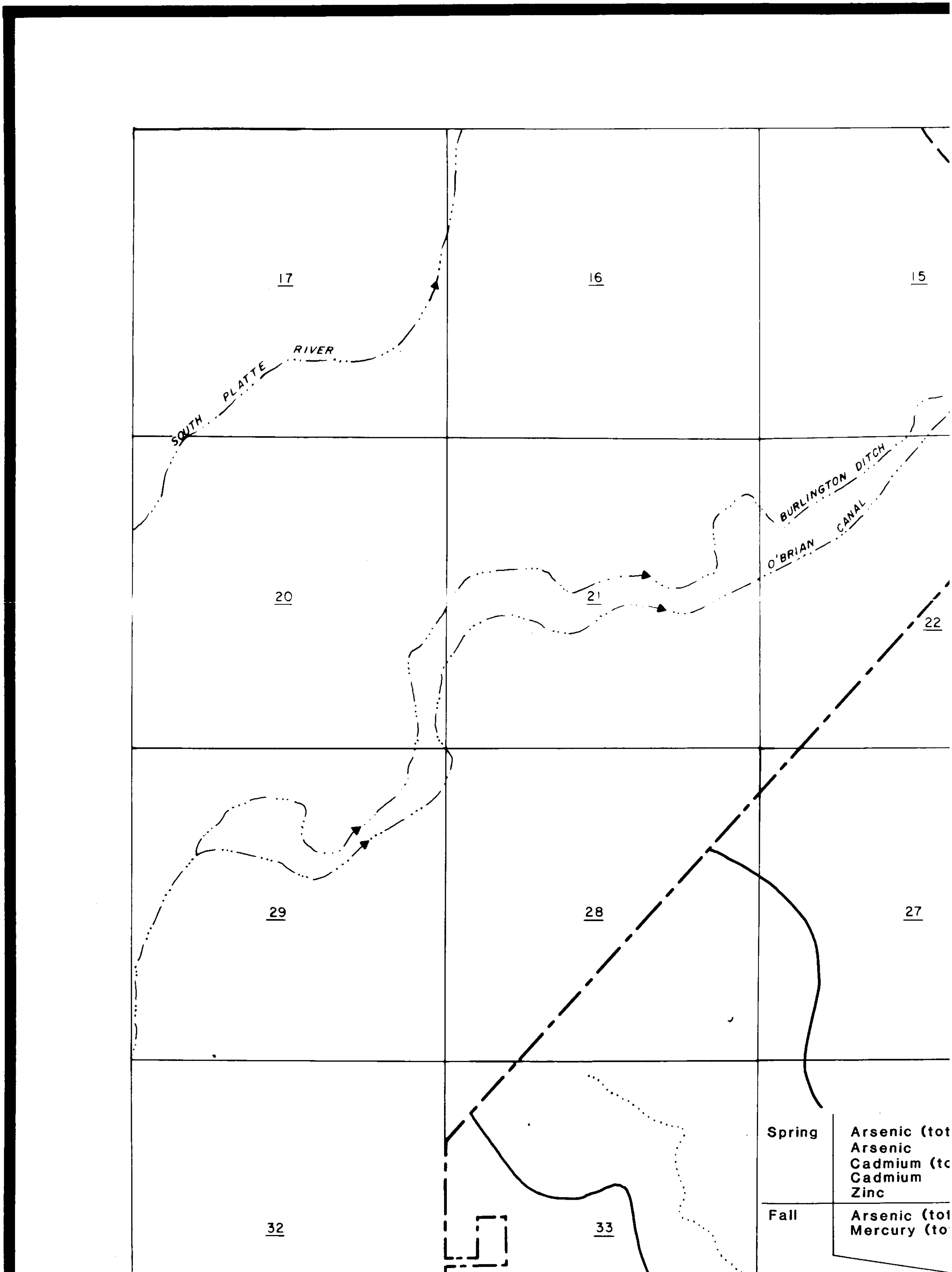
R.L. Stollar & Associates, Inc.

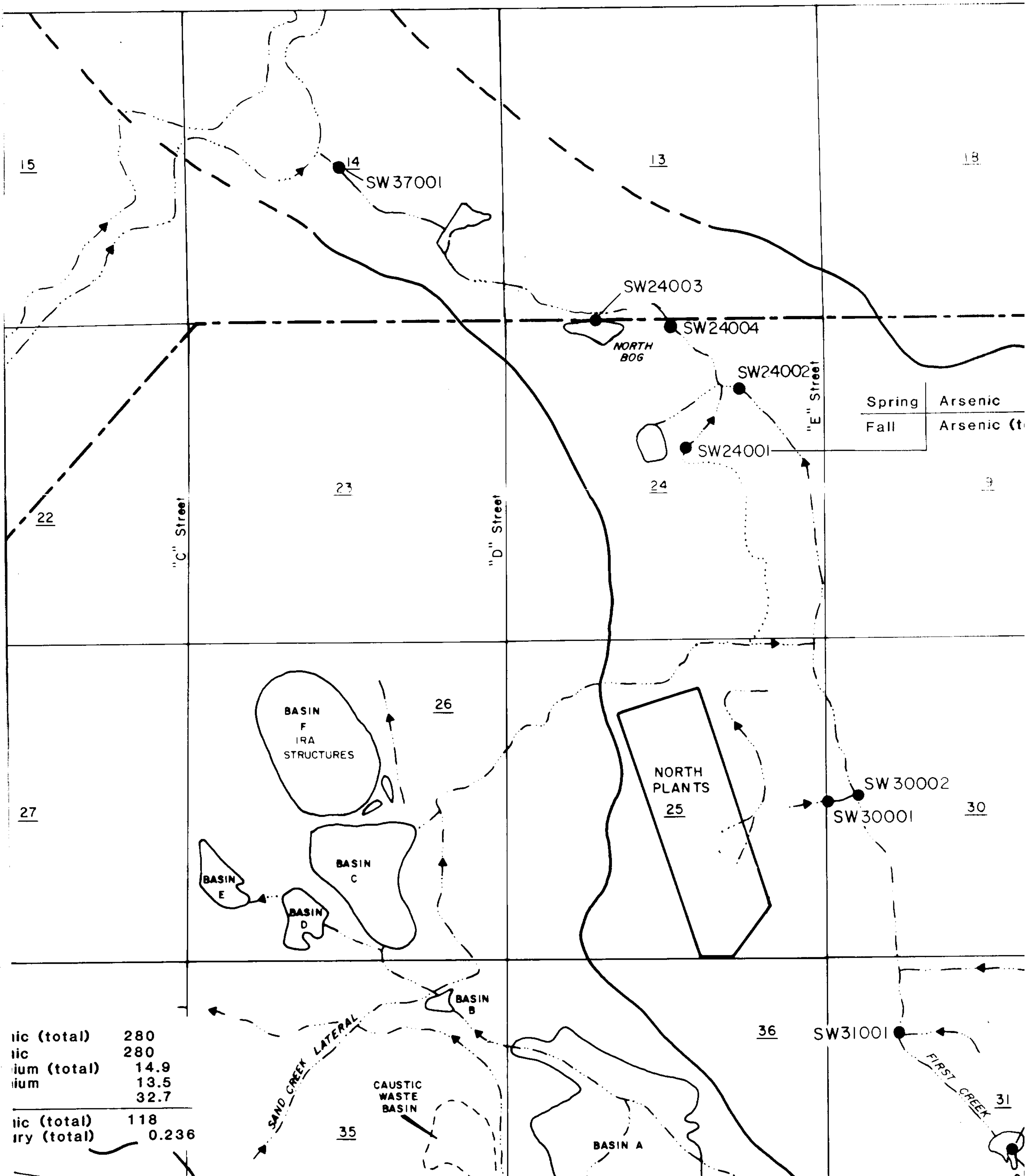
Harding Lawson Associates

Plate 4.2-1

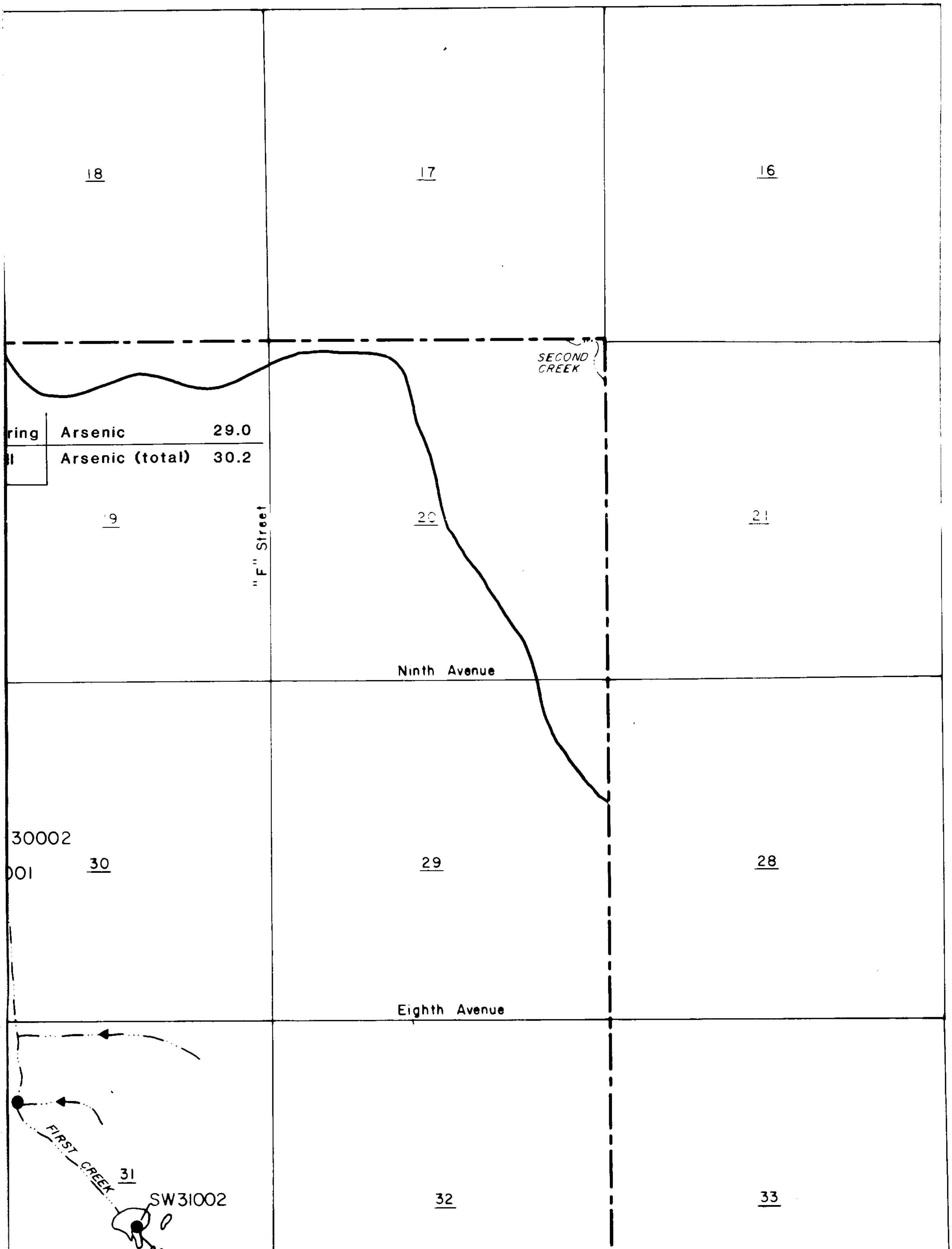
WY89 Occurrences of CMP Surface-Water Target Organic Compounds

CMP SW FY89

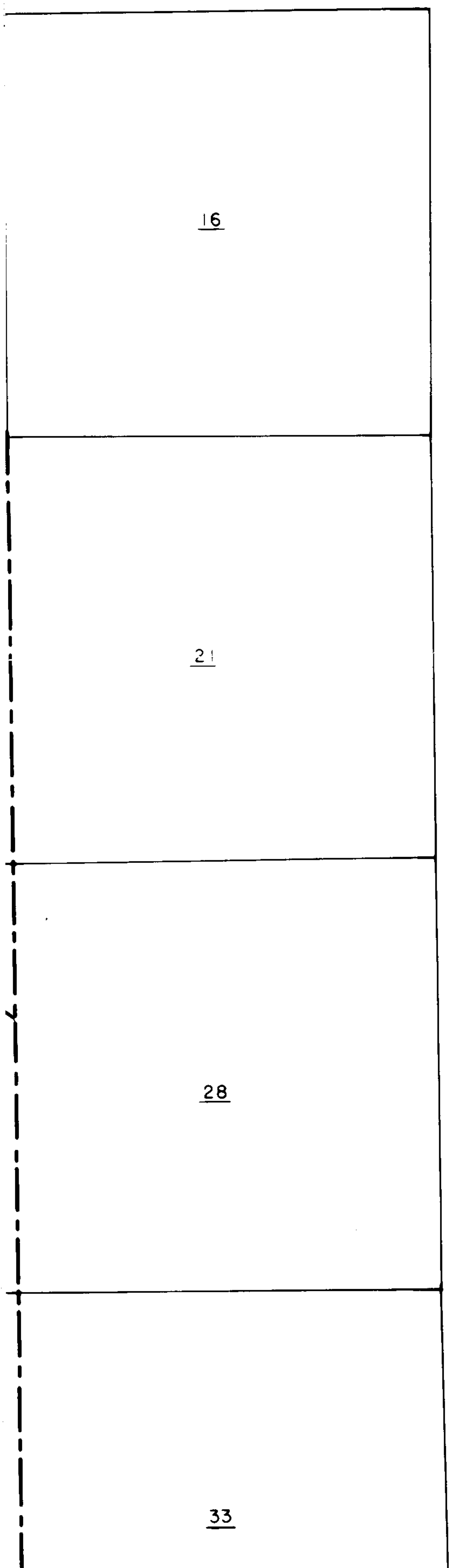

17
16
15
SOUTH PLATTE RIVER
20
21
22
BURLINGTON DITCH
O'BRIAN CANAL
29
28
27
32
33
Spring
Arsenic
Arsenic
Cadmium
Cadmium
Zinc
Fall
Arsenic
Mercury



15
14
SW37001
13
18
SW24003
SW24004
NORTH BOG
SW24002
"E" Street
Spring
Arsenic
Fall
Arsenic (t
SW24001
22
"C" Street
23
"D" Street
24
26
BASIN F IRA STRUCTURES
NORTH PLANTS 25
SW30002
SW30001
27
30
BASIN C
BASIN E
BASIN D
BASIN B
36
SW31001
ic (total) 280
ic 280
ium (total) 14.9
ium 13.5
32.7
ic (total) 118
ry (total) 0.236
SAND CREEK LATERAL
CAUSTIC WASTE BASIN
35
BASIN A
FIRST CREEK
31



18
17
16
SECOND CREEK
ring Arsenic 29.0
l Arsenic (total) 30.2
19
20
21
"F" Street
Ninth Avenue
30002
30
001
29
28
Eighth Avenue
FIRST CREEK
31
SW31002
32
33



Legend

20	Section Number
	Lake, Pond or Basin
	Stream or Ditch with Flow Direction
	Abandoned Stream or Ditch
SW24001	Surface Water Sample Location
	Arsenal Boundary

Sampling Summary

Spring (4/18-5/18/89) 26 Sites

SW01001	SW08003	SW24002
SW01002	SW11001	SW24003
SW01004	SW11002	SW24004
SW01005	SW11003	SW30002
SW02003	SW12001	SW31001
SW02004	SW12003	SW31002
SW02006	SW12004	SW36001
SW07001	SW12005	SW37001
SW08001	SW24001	

Storm Events 7 Sites

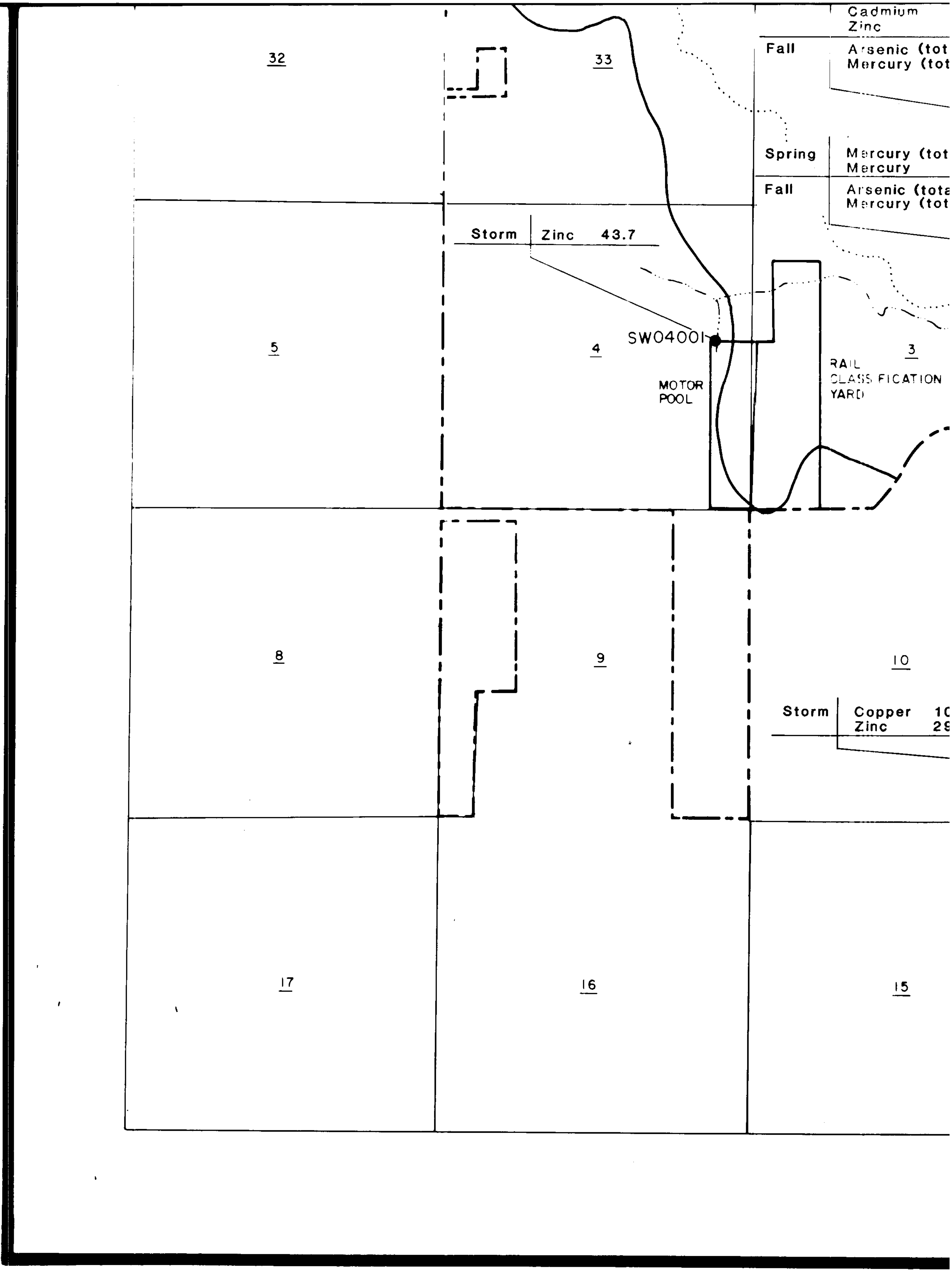
SW04001	SW11002	SW24002
SW08003	SW12002	
SW11001	SW12005	

Fall (9/25-9/28/89) 12 Sites

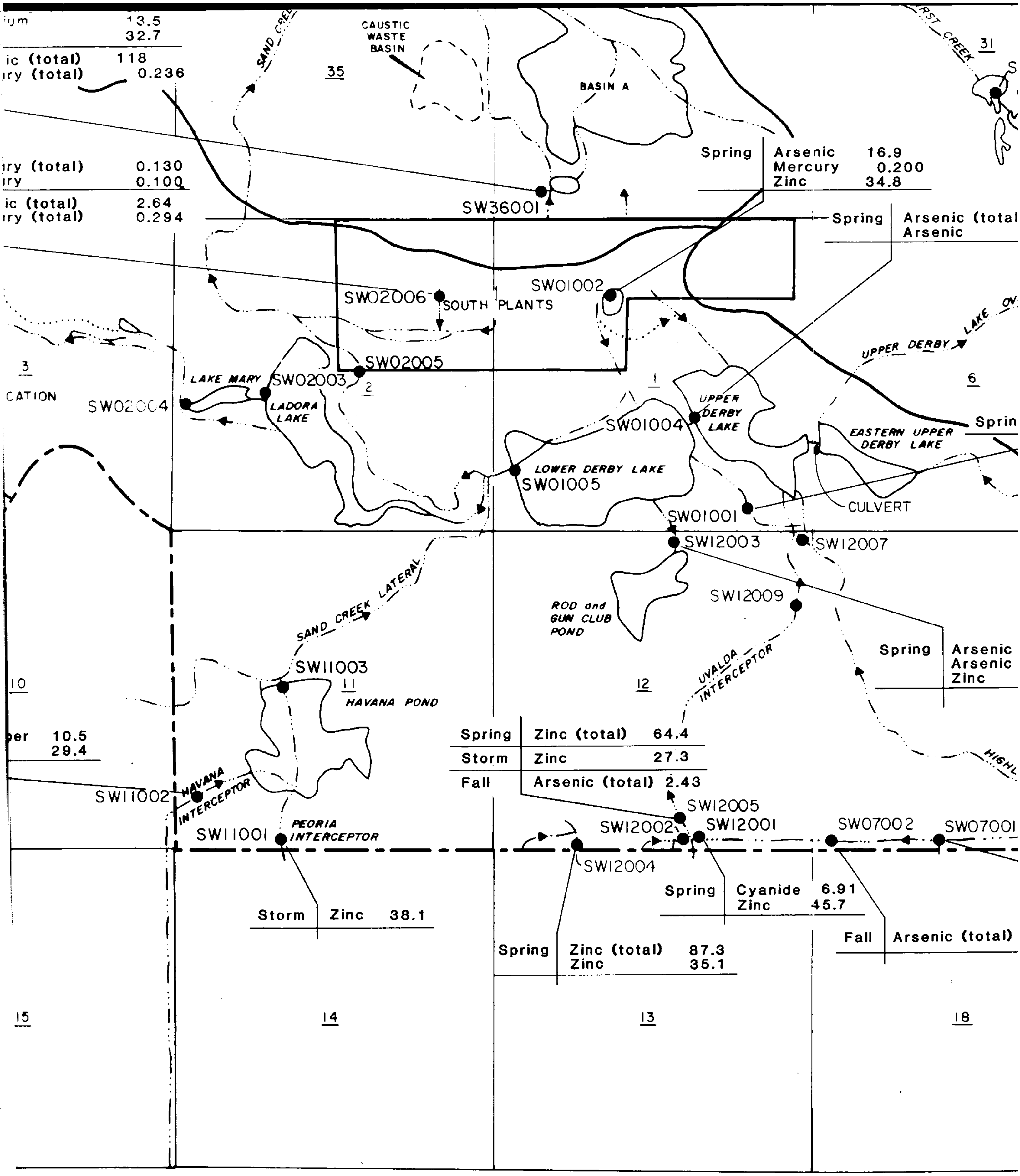
SW01001	SW08003	SW12004
SW02006	SW11001	SW12005
SW07001	SW11002	SW24001
SW07002	SW12001	SW36001

All concentrations in µg/l.

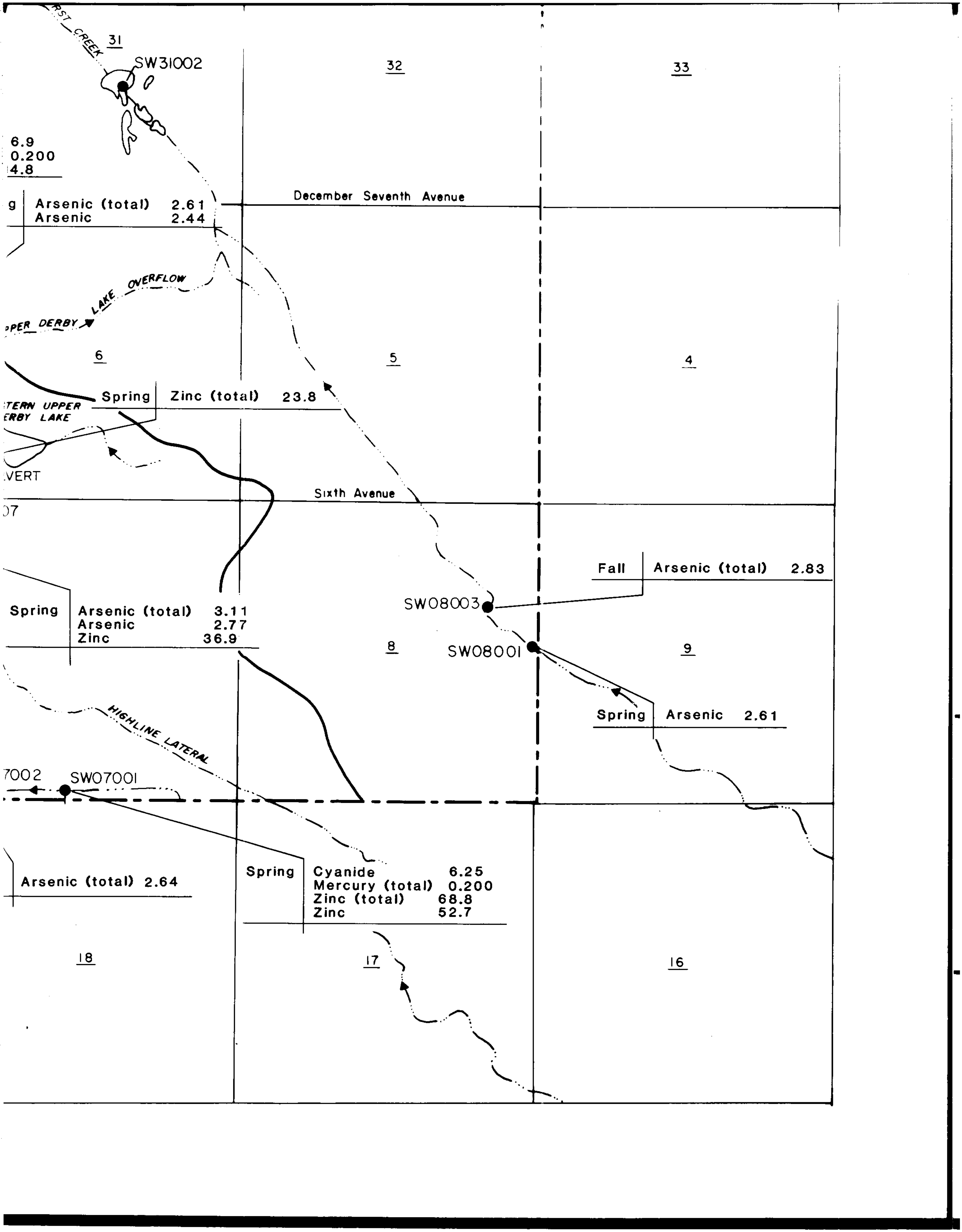
Concentrations for dissolved constituents



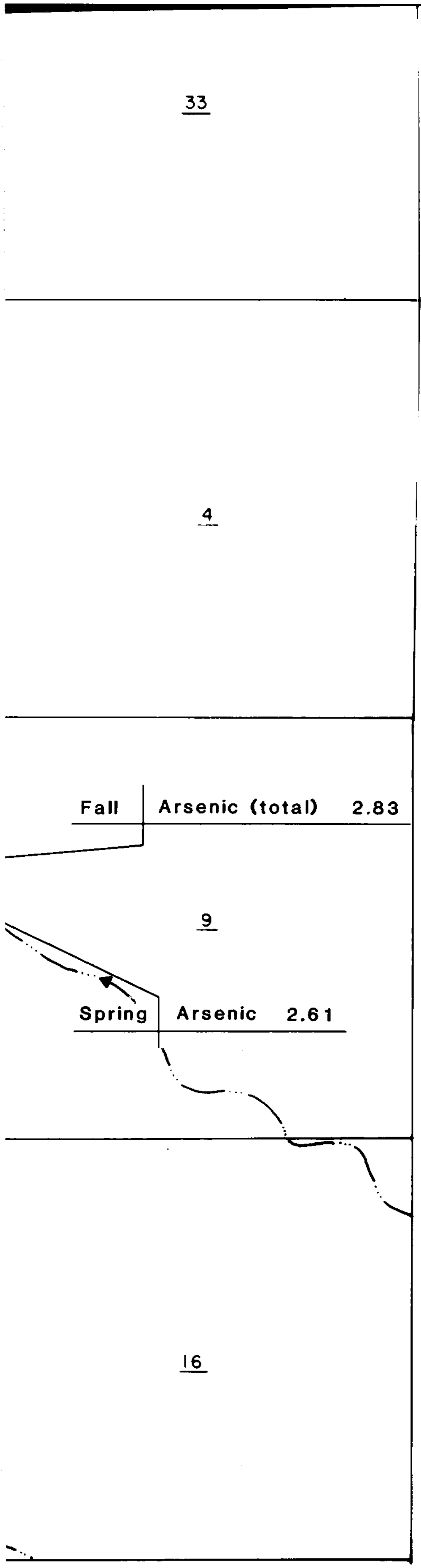
Cadmium
Zinc
Fall
Arsenic (tot
Mercury (tot
Spring
Mercury (tot
Mercury
Fall
Arsenic (tota
Mercury (tot
32
33
Storm
Zinc 43.7
SW04001
5
4
3
MOTOR
POOL
RAIL
CLASSIFICATION
YARD
8
9
10
Storm
Copper 10
Zinc 29
17
16
15



ium 13.5
32.7
ic (total) 118
iry (total) 0.236
iry (total) 0.130
iry 0.100
ic (total) 2.64
iry (total) 0.294
SAND CREEK
CAUSTIC WASTE BASIN
35
BASIN A
31
Spring | Arsenic 16.9
Mercury 0.200
Zinc 34.8
SW36001
Spring | Arsenic (total
Arsenic
SW02006
SOUTH PLANTS
SW01002
SW02005
UPPER DERBY LAKE
3
CATION
LAKE MARY
SW02003
2
1
6
SW02004
LADORA LAKE
UPPER DERBY LAKE
SW01004
EASTERN UPPER DERBY LAKE
Sprin
LOWER DERBY LAKE
SW01005
CULVERT
SW01001
SW12003
SW12007
SAND CREEK LATERAL
ROD and GUN CLUB POND
SW12009
Spring | Arsenic
Arsenic
Zinc
SW11003
10
11
HAVANA POND
12
UVALDA INTERCEPTOR
ber 10.5
29.4
Spring | Zinc (total) 64.4
Storm | Zinc 27.3
Fall | Arsenic (total) 2.43
HIGHL
SW11002
HAVANA INTERCEPTOR
SW12005
SW11001
PEORIA INTERCEPTOR
SW12002
SW12001
SW07002
SW07001
SW12004
Spring | Cyanide 6.91
Zinc 45.7
Storm | Zinc 38.1
Fall | Arsenic (total)
Spring | Zinc (total) 87.3
Zinc 35.1
15
14
13
18



RST CREEK
31
SW31002
32
33
6.9
0.200
4.8
December Seventh Avenue
g
Arsenic (total) 2.61
Arsenic 2.44
LAKE OVERFLOW
PPER DERBY
6
5
4
Spring
Zinc (total) 23.8
TERN UPPER
ERBY LAKE
VERT
Sixth Avenue
07
Fall
Arsenic (total) 2.83
SW08003
Spring
Arsenic (total) 3.11
Arsenic 2.77
Zinc 36.9
8
SW08001
9
Spring
Arsenic 2.61
HIGHLINE LATERAL
7002
SW07001
Arsenic (total) 2.64
Spring
Cyanide 6.25
Mercury (total) 0.200
Zinc (total) 68.8
Zinc 52.7
18
17
16



All concentrations in µg/l.

Concentrations for dissolved constituents unless otherwise noted.

Drainage Basin Boundary

N

0 2000 4000
FEET

Prepared for:

U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

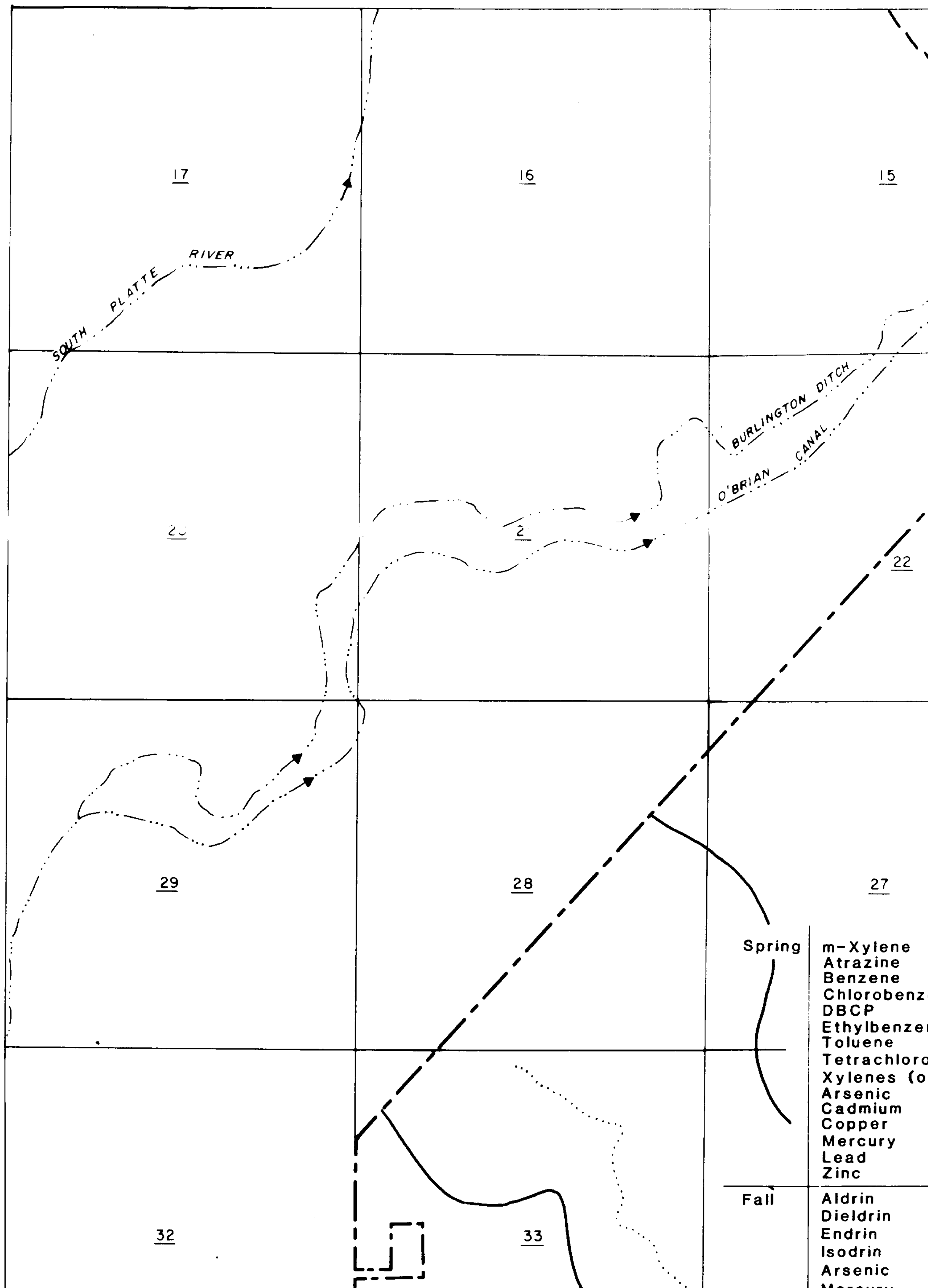
Prepared by:

R.L. Stollar & Associates, Inc.
Harding Lawson Associates

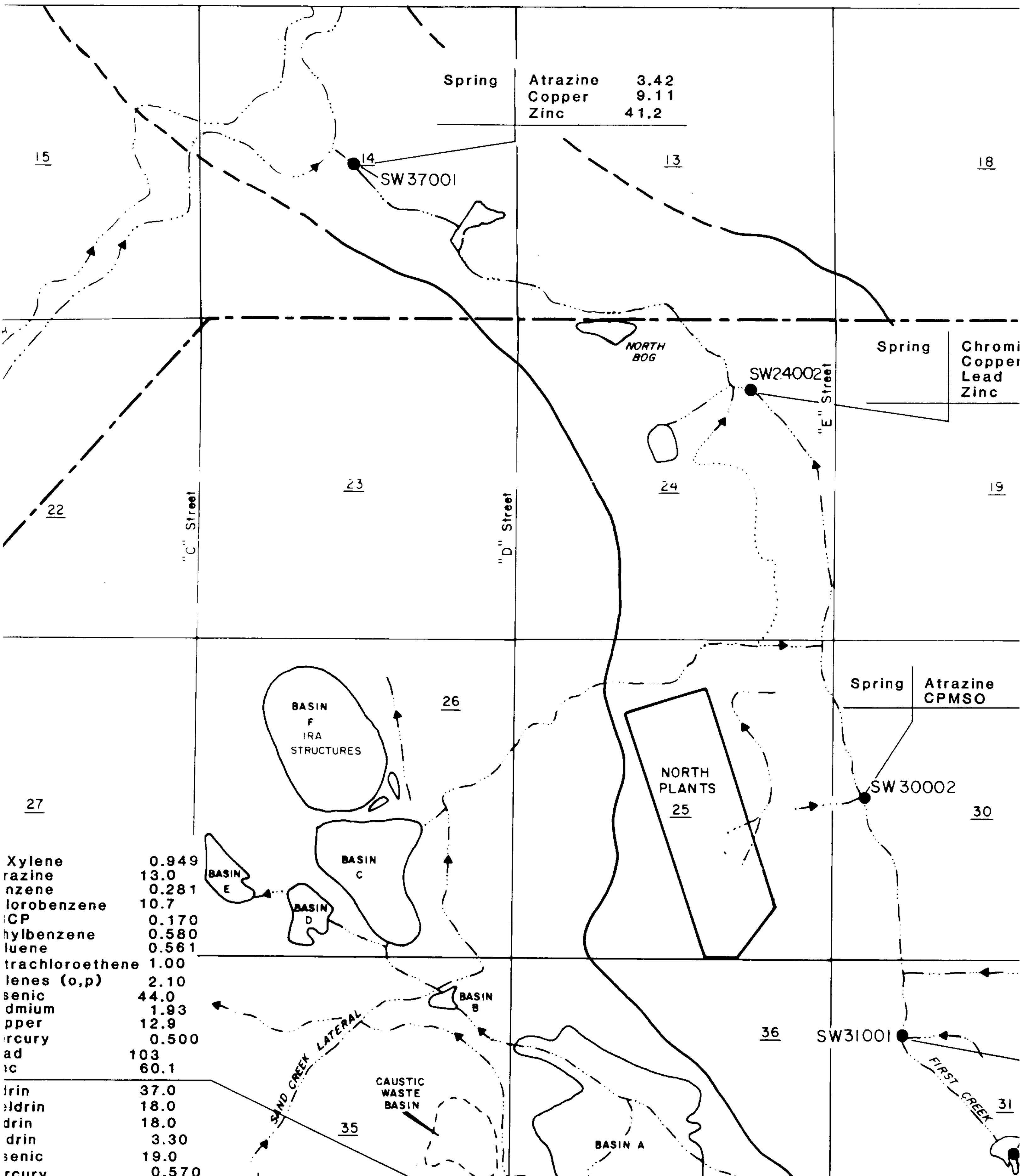
Plate 4.2-2

WY89 Occurrences of CMP Surface-Water Target Inorganic Constituents

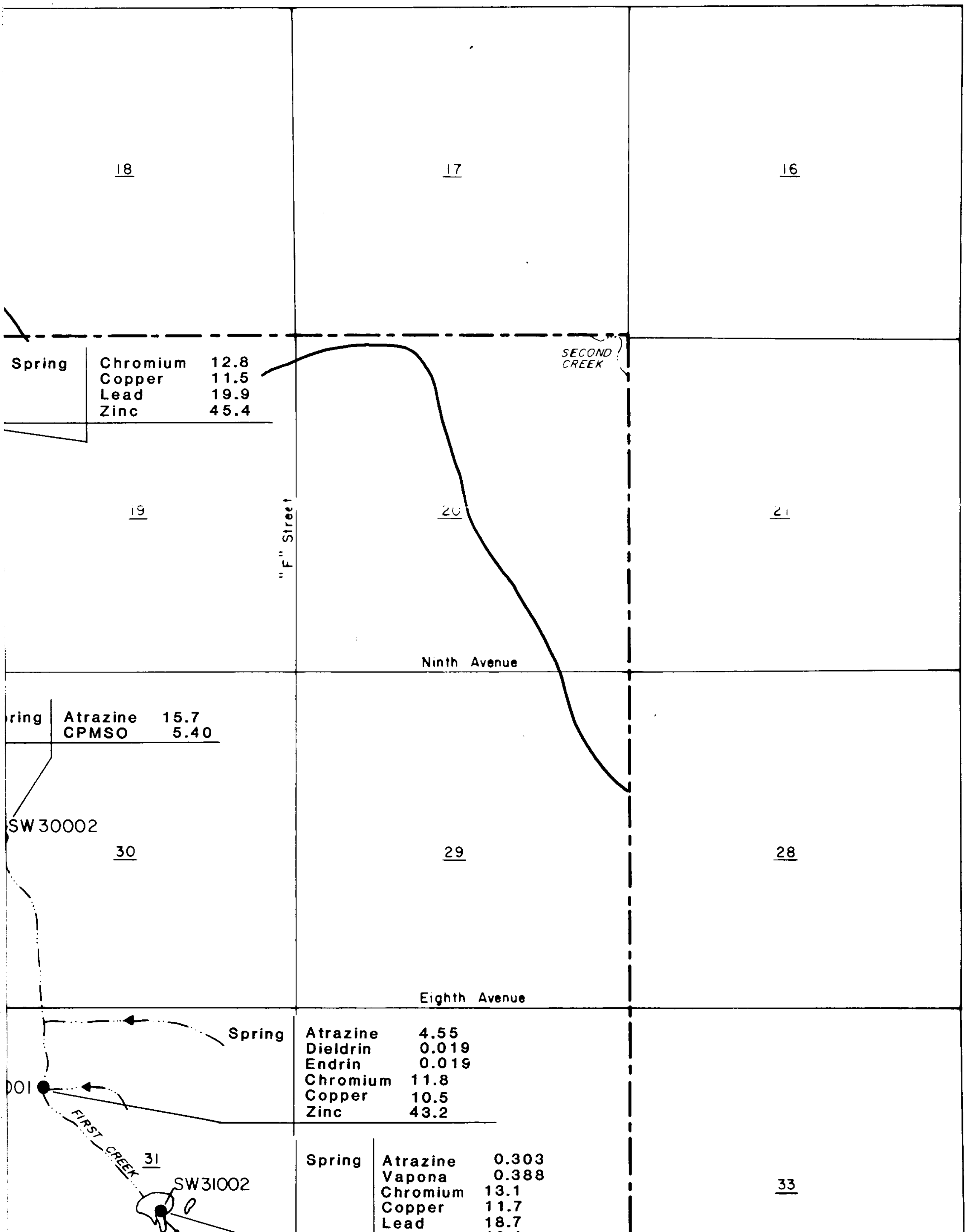
CMP SW FY89

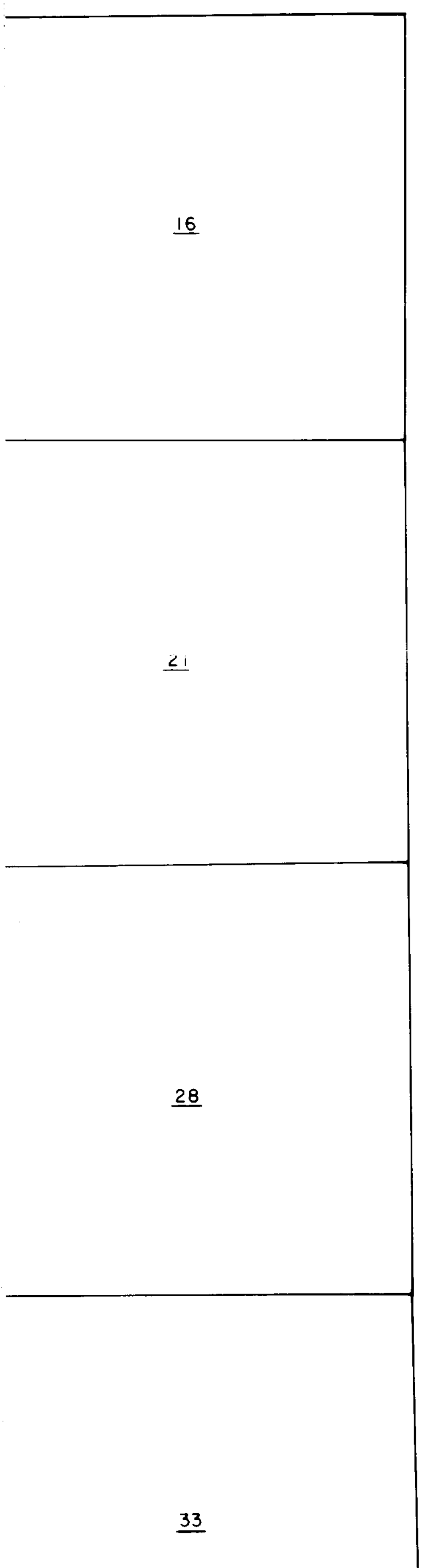


17
16
15
SOUTH PLATTE RIVER
BURLINGTON DITCH
O'BRIAN CANAL
22
29
28
27
32
33
Spring
m-Xylene
Atrazine
Benzene
DBCP
Toluene
Arsenic
Cadmium
Copper
Mercury
Lead
Zinc
Fall
Aldrin
Dieldrin
Endrin
Isodrin
Arsenic



Spring
Atrazine 3.42
Copper 9.11
Zinc 41.2
15
14
SW37001
13
18
NORTH BOG
SW24002
"E" Street
Spring
Chromi
Copper
Lead
Zinc
22
"C" Street
23
"D" Street
24
19
26
BASIN F IRA STRUCTURES
Spring
Atrazine
CPMSO
NORTH PLANTS
25
SW30002
27
30
BASIN C
BASIN E
BASIN D
Xylene 0.949
razine 13.0
nzene 0.281
lorobenzene 10.7
CP 0.170
hylbenzene 0.580
luene 0.561
trachloroethene 1.00
lenes (o,p) 2.10
senic 44.0
dmium 1.93
pper 12.9
rcury 0.500
ad 103
c 60.1
rin 37.0
ldrin 18.0
drin 18.0
drin 3.30
senic 19.0
rcury 0.570
BASIN B
SAND CREEK LATERAL
36
SW31001
FIRST CREEK
CAUSTIC WASTE BASIN
35
BASIN A
31


18
17
16
Spring
Chromium 12.8
Copper 11.5
Lead 19.9
Zinc 45.4
SECOND CREEK
19
"F" Street
20
21
Ninth Avenue
ring
Atrazine 15.7
CPMSO 5.40
SW 30002
30
29
28
Eighth Avenue
Spring
Atrazine 4.55
Dieldrin 0.019
Endrin 0.019
Chromium 11.8
Copper 10.5
Zinc 43.2
001
FIRST CREEK
31
SW31002
Spring
Atrazine 0.303
Vapona 0.388
Chromium 13.1
Copper 11.7
Lead 18.7
33



Legend

20 — Section Number

Lake, Pond or Basin

Stream or Ditch with Flow Direction

Abandoned Stream or Ditch

SW24001 — Surface Water Sample Location

Arsenal Boundary

Sediment Sampling Summary

Spring (4/18–5/18/89) 17 Sites

SW01001	SW11001	SW30002
SW01002	SW11002	SW31001
SW02006	SW12003	SW31002
SW07001	SW12004	SW36001
SW08001	SW12005	SW37001
SW08003	SW24002	

Fall (9/25–9/28/89) 5 Sites

SW02006	SW11001	SW36001
SW08003	SW12005	

*Organosulfur compound and mercury analyses only.

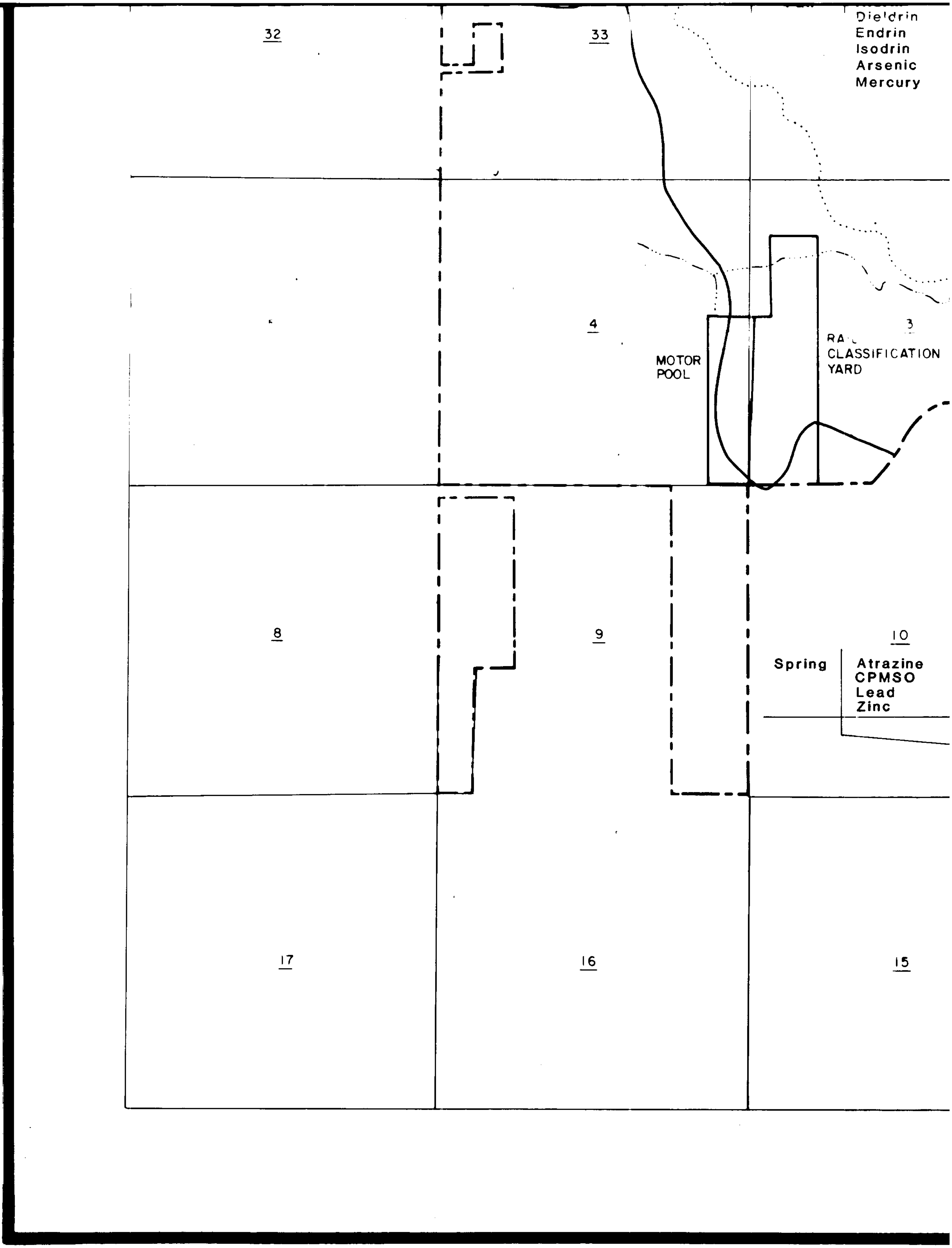
Acronyms

CPMSO — P-chlorophenylmethyl sulfoxide

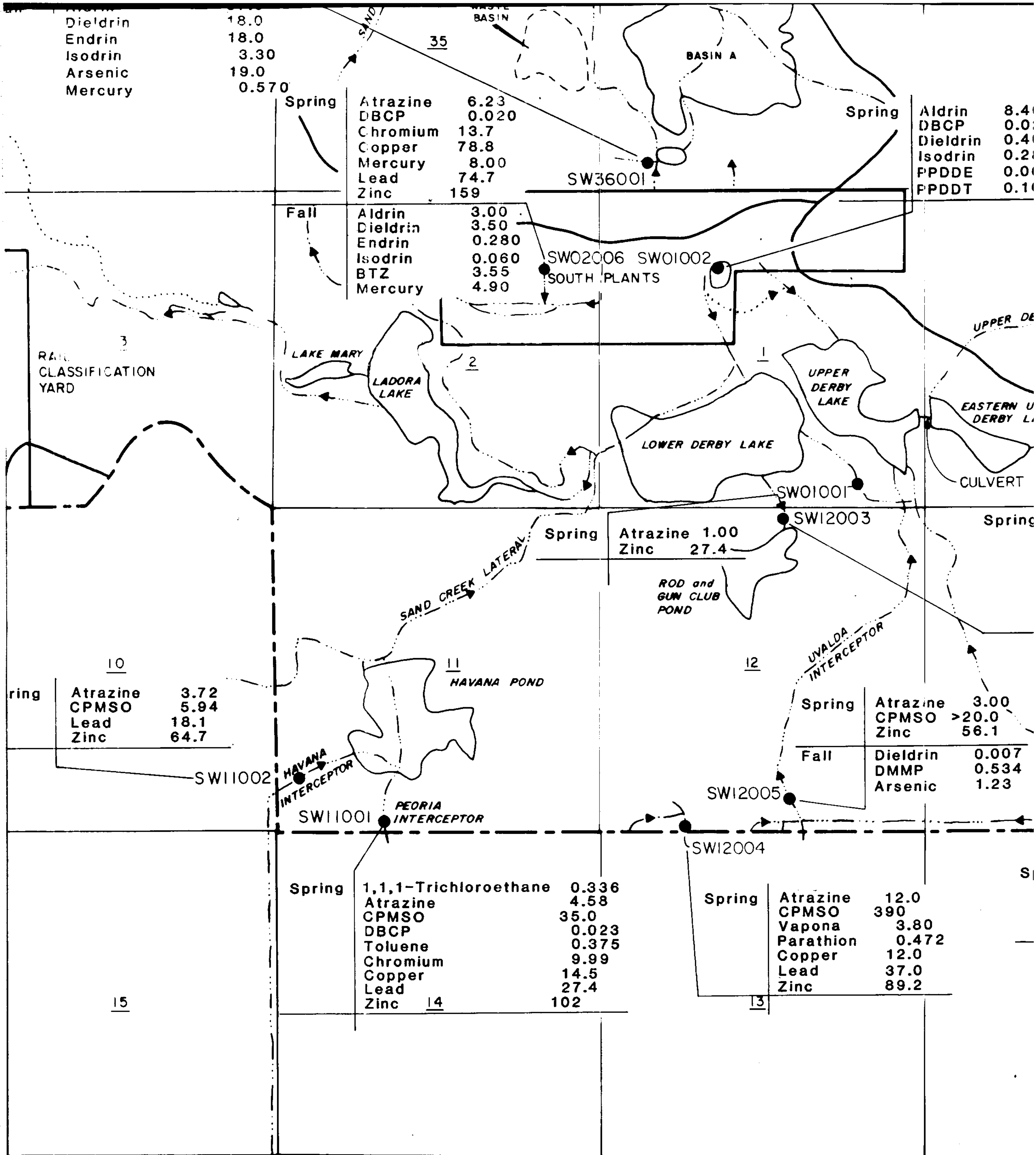
DBCP — Dibromochloropropane

All concentrations in µg/l.

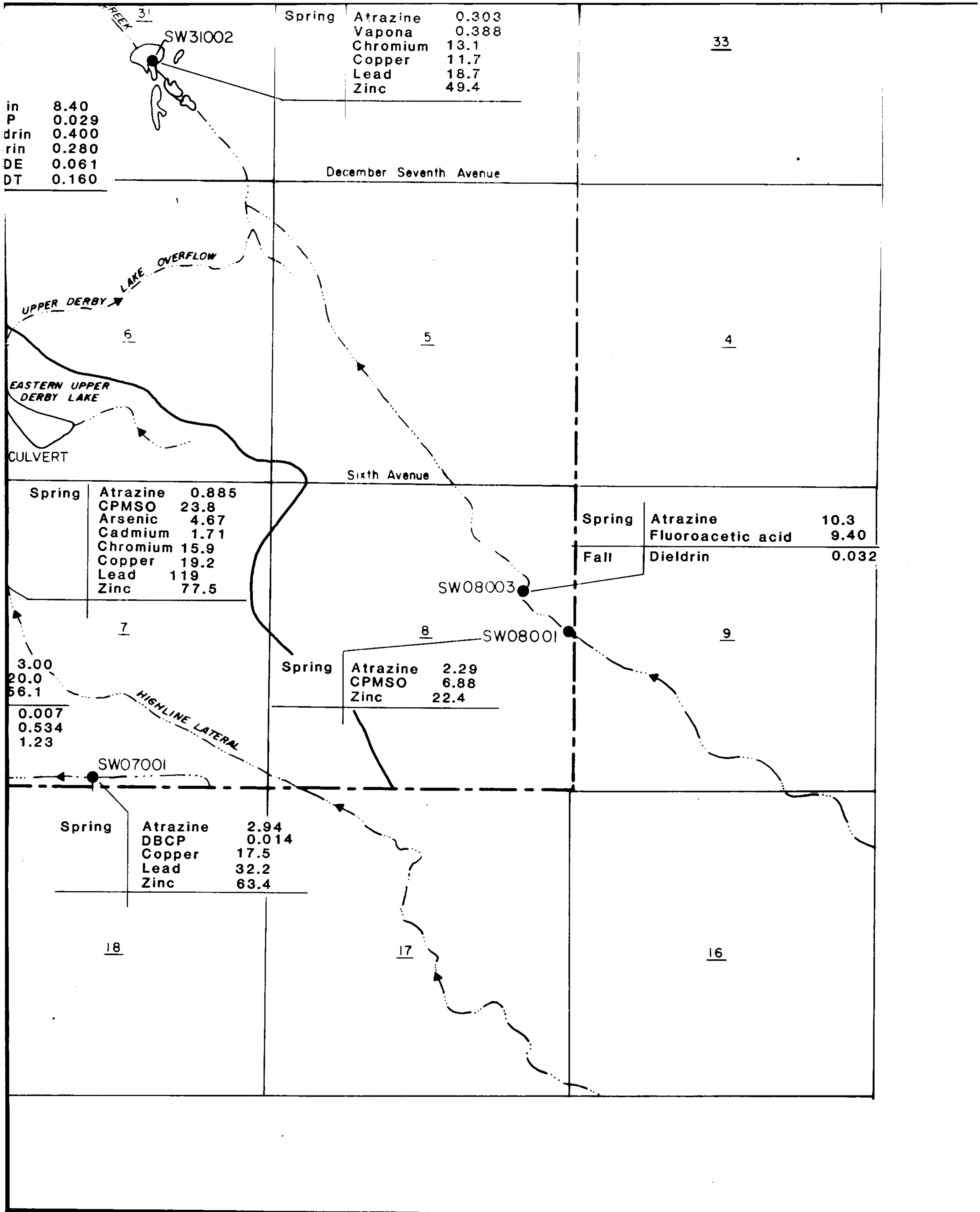
Drainage Basin Boundary



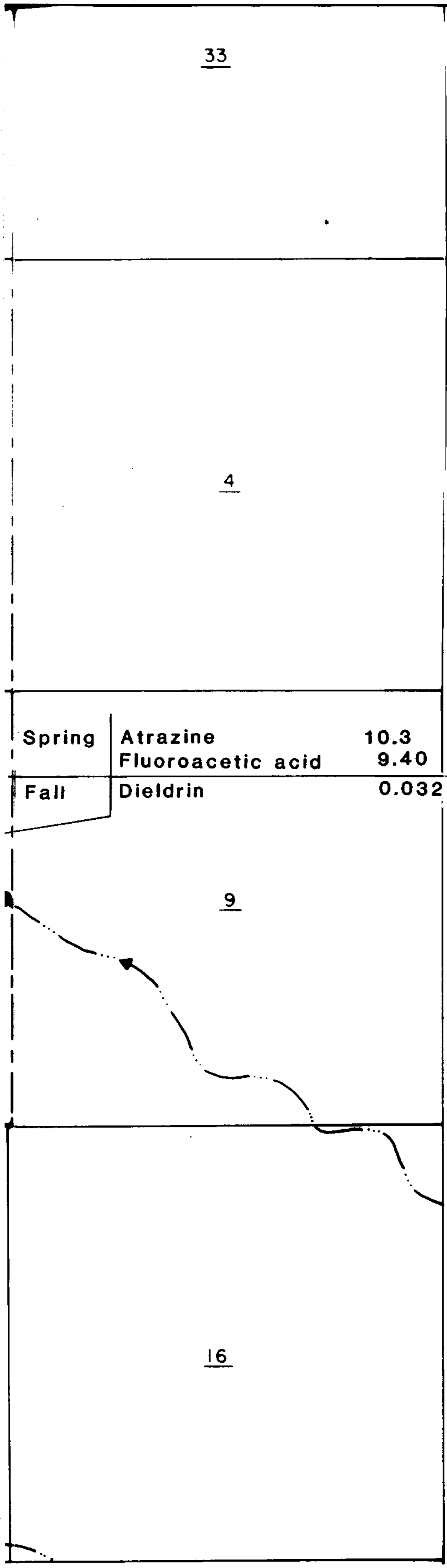
32
33
Dieldrin
Endrin
Isodrin
Arsenic
Mercury
4
3
MOTOR POOL
CLASSIFICATION YARD
8
9
10
Spring
Atrazine
CPMSO
Lead
Zinc
17
16
15

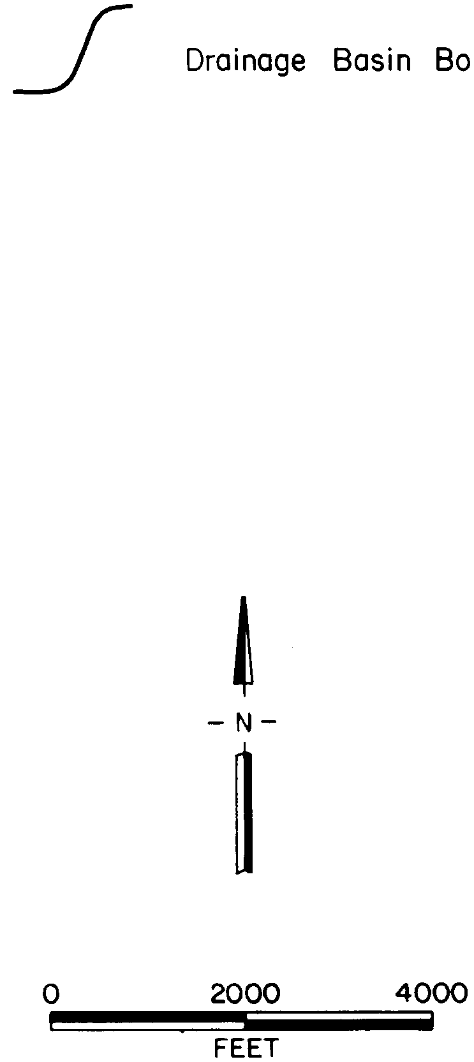


Dieldrin 18.0
Endrin 18.0
Isodrin 3.30
Arsenic 19.0
Mercury 0.570
BASIN
35
BASIN A
Spring
Atrazine 6.23
DBCP 0.020
Chromium 13.7
Copper 78.8
Mercury 8.00
Lead 74.7
Zinc 159
Fall
Aldrin 3.00
Dieldrin 3.50
Endrin 0.280
Isodrin 0.060
BTZ 3.55
Mercury 4.90
SW36001
Spring
Aldrin 8.4
DBCP 0.0
Dieldrin 0.4
Isodrin 0.2
PPDDE 0.0
PPDDT 0.1
SW02006
SW01002
SOUTH PLANTS
3
RAIL
CLASSIFICATION
YARD
LAKE MARY
LADORA LAKE
2
1
UPPER DERBY LAKE
UPPER DE
EASTERN U
DERBY L
LOWER DERBY LAKE
CULVERT
SW01001
SW12003
Spring
Atrazine 1.00
Zinc 27.4
Spring
ROD and GUN CLUB POND
SAND CREEK LATERAL
10
11
HAVANA POND
12
UVALDA INTERCEPTOR
Spring
Atrazine 3.72
CPMSO 5.94
Lead 18.1
Zinc 64.7
Spring
Atrazine 3.00
CPMSO >20.0
Zinc 56.1
Fall
Dieldrin 0.007
DMMP 0.534
Arsenic 1.23
SW11002
HAVANA INTERCEPTOR
SW12005
SW11001
PEORIA INTERCEPTOR
SW12004
Spring
1,1,1-Trichloroethane 0.336
Atrazine 4.58
CPMSO 35.0
DBCP 0.023
Toluene 0.375
Chromium 9.99
Copper 14.5
Lead 27.4
Zinc 102
14
Spring
Atrazine 12.0
CPMSO 390
Vapona 3.80
Parathion 0.472
Copper 12.0
Lead 37.0
Zinc 89.2
13
15



31
SW31002
Spring
Atrazine 0.303
Vapona 0.388
Chromium 13.1
Copper 11.7
Lead 18.7
Zinc 49.4
33
in 8.40
P 0.029
drin 0.400
rin 0.280
DE 0.061
DT 0.160
December Seventh Avenue
UPPER DERBY LAKE OVERFLOW
6
5
4
EASTERN UPPER DERBY LAKE
CULVERT
Sixth Avenue
Spring
Atrazine 0.885
CPMSO 23.8
Arsenic 4.67
Cadmium 1.71
Chromium 15.9
Copper 19.2
Lead 119
Zinc 77.5
Spring
Atrazine 10.3
Fluoroacetic acid 9.40
Fall
Dieldrin 0.032
SW08003
7
8
SW08001
9
3.00
20.0
56.1
0.007
0.534
1.23
Spring
Atrazine 2.29
CPMSO 6.88
Zinc 22.4
HIGHLINE LATERAL
SW07001
Spring
Atrazine 2.94
DBCP 0.014
Copper 17.5
Lead 32.2
Zinc 63.4
18
17
16





Prepared for:

U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.
Harding Lawson Associates

Plate 4.3-1

FY89 CMP Organic and Trace Inorganic Compound Detections in Stream Bottom Sediments

CMP SW FY89

5.0 DATA ASSESSMENT

5.1 Surface-Water Quantity Data Assessment

Surface-water quantity data and results obtained in Water Year 1989 are discussed in the following sections. Significant differences from previous years, apparent trends, anomalies, etc., are identified.

5.1.1 Stream Flow Data

Items of interest in a stream flow monitoring program include relative flow rates and volumes as well as variability of flow.

5.1.1.1 Rates and Volumes of Flow. The stations that had the largest rates and volumes of flow during Water Year 1989 were those measuring inflow to RMA, totaling 1,980 ac-ft for the six months of April through September. This is consistent with previous years, except the amount delivered by the Highline Lateral was lower than usual. The irrigation canal carried water to RMA during six days in October 1988 and only 22 days during the summer of 1989. The Irondale Gulch drainage basin produced about 60 percent of the total inflow onto RMA with nearly 85 percent of the inflow coming from natural runoff.

Of the other four offsite sources, the Havana Interceptor conveyed the largest volume of water to RMA -- over 518 ac-ft during May through September (May only partially measured). This volume represents a unit runoff from the 5.22 sq mi drainage area of 1.86 in, about 17.90 percent of the precipitation measured at Stapleton Airport during the same period of time. This unit runoff is comparable to that of 1986 (1.71 in), but lower than the 3.25 in and 2.55 in unit runoff in 1987 and 1988, respectively. A downward trend exists in the 1986-1989 runoff expressed in percentages of the measured Stapleton precipitation (34.1, 28.2, 24.3, 17.9) but the significance is unknown. More than likely it is related to variations in rainfall patterns not adequately reflected by a single gage. The volume of inflow to RMA via the Havana Interceptor was about 44 percent of the total Irondale Gulch drainage basin inflow in Water Year 1989, although the drainage area is only about 38 percent of the total RMA drainage.

The second largest, natural inflow to RMA during Water Year 1989 was measured at the South Uvalda monitoring station. During the five months of May through September an inflow to RMA of 410.48 ac-ft was measured. The unit runoff from its 7.8 sq mi drainage area was 0.99 inches, about one-half that of the Havana Interceptor. The unit runoff for these five months over the four years of records has been quite consistent (0.72, 1.03, 0.87 and 0.99 in). During the last three years the runoff expressed as a percentage of the Stapleton precipitation has been very consistent (8.9, 8.3 and 9.6). The percentage in 1986 was higher, 14.3 percent, probably due to rainfall patterns. Although the drainage area contributing to the South Uvalda is over 57 percent of the Irondale Gulch drainage basin above RMA, the volume of runoff produced was only 35 percent of the total in Water Year 1989.

The stream flow gages measuring the smallest (Peoria Interceptor - 0.644 sq mi) and the largest (First Creek - 26.38 sq mi) drainage areas measured about the same volume of flow during the May through September period in 1989. The volume measured at the Peoria Interceptor gage was 253.77 ac-ft compared to 220.29 ac-ft at South First Creek.

The unit runoff of the Peoria Interceptor drainage area was 7.39 in, 71.5 percent of the Stapleton precipitation. This unit runoff, though comparable to the 7.19 in of 1988, is considerably higher than the 1.55 and 3.23 in for 1986 and 1987, respectively. Likewise, the runoff as a percentage of the Stapleton precipitation was considerably higher in 1988 and 1989 (68.7 and 71.5 percent) compared to 1986 and 1987 (30.9 and 28.0 percent). Although it is possible rainfall patterns could be a partial cause of this large difference; one has the suspicion that major changes in the watershed have taken place, such as more impermeable surfaces and more irrigation.

The five month runoff volume entering RMA via First Creek was 220.29 ac-ft, a unit runoff of only 0.16 inch. This is comparable to the 0.12 in unit runoff for 1986, but substantially smaller than the 0.35 in and 0.28 in unit runoffs of 1987 and 1988, respectively. As a percentage of the Stapleton precipitation, 1.5 percent, it is lower than any of the preceding years (2.4, 3.0 and 2.7 percent). The differences are most likely caused by differences in rainfall intensities and amounts that can occur over a watershed area of this size during the summer thunderstorm season. An intense storm centering on a developed portion, as opposed to an undeveloped portion of the watershed, can result in a significantly different runoff.

The measured outflow of First Creek at the North First Creek monitoring station, although including 10.32 additional sq mi of drainage area and imported water, was significantly less than the inflow at South First Creek (146.7 ac-ft vs. 220.29 ac-ft, May through September). This relationship is typical of previous years and represents a loss of surface flow to infiltration, evaporation and transpiration. The 146.7 ac-ft volume is a unit runoff of only 0.07 in from the 36.70 sq mi drainage area, about 0.7 percent of the precipitation measured at Stapleton Airport during the same time period.

5.1.1.2 Variability of Flow Rates. The variability of flow rates affects the accuracy of measurement, the more variable being generally the most difficult to measure accurately. The ratio of the daily maximum discharge to the mean daily discharge is an index of variability. These indices calculated monthly for Water Year 1989 are shown in Table 5.1-1 for the 11 stream gaging stations.

As would be expected, those stations which carry runoff in response to rainfall events tend to have a higher index of variability than those controlled by man. However, the North Uvalda station during May and June, and the Highline Lateral during June are exceptions.

A second index, the ratio of the instantaneous maximum discharge to the mean daily discharge displays somewhat the same pattern, as shown in Table 5.1-2. The flows in the Havana Interceptor were the most variable, considerably more so than flows from the other two small offsite tributary drainages, Peoria Interceptor and South Uvalda. Maximum discharges at South First Creek were relatively small in comparison to the mean daily discharge.

5.1.2 Lake and Pond Stage Data

Average monthly stage values for Upper Derby Lake, Ladora Lake, Lake Mary, and Havana Pond for Water Years 1986 through 1989 are presented in Table 5.1-3. Stage/volume and stage/area relationships have been established by previous contractors (Ebasco Services, Inc., 1989, Appendix A-2). Weekly stage readings were started by CMP in April, 1988. Stage data reported in Table 5.1-2 for the period from October, 1985 to December, 1987 were taken from the WRI report (Ebasco Services, 1989). Sections 5.1.2.1 - 5.1.2.5 compare historical stage data to that compiled by the surface-water CMP.

5.1.2.1 Upper Derby Lake. Upper Derby Lake was essentially dry from mid 1986 until May 1988. It reached maximum storage during Water Year 1988 in July 1988, then stayed at stages of five ft to over six ft through the first two months of Water Year 1989. As in the past water year, storage was drawn down to zero by March 1989, then increased again to a maximum in June. The maximum stage was 7.70 ft (5255.47 ft-msl), measured June 6, 1989, representing about 48.96 ac-ft of storage volume.

5.1.2.2 Lower Derby Lake. Historically the stage of Lower Derby Lake has fluctuated between about 14 and 17 ft without a definable seasonal pattern. The stages in Water Year 1989, however stayed between 16.9 ft (5247.07 ft-msl) and 15.00 ft (5245.17 ft-msl) through May 1989,

Table 5.1-1 Ratio of Daily Maximum Discharge to Mean Daily Discharge

	Oct. '88	Apr. '89	May '89	June '89	July '89	Aug. '89	Sept. '89
			(dimensionless)				
Irondale Gulch Drainage Basin							
Havana Interceptor	1.3	4.2*	8.6*	14.4	23.7	4.7	5.0
Peoria Interceptor	2.4	7.0*	6.0	15.8	15.0	7.2	6.2
Ladora Weir	9.1	NR	--	--	11.8	1.6	1.5
South Uvalda	1.2	8.0*	6.2	8.0	11.8	9.4	5.5
North Uvalda	1.1	NR	28.3	18.6	--	2.7	1.2
Highline Lateral	6.6	--	3.5	20.6	--	15.6	--
South Plants Ditch	--	--	--	3.8	--	--	--
First Creek Drainage Basin							
South First Creek	NR	1.7*	3.7	2.2	10.0	8.5	5.1
North First Creek	NR	1.7*	3.0	3.3	--	--	--
First Creek Off-Post	NR	NR	NR	NR	3.0*	NR	NR
South Platte Drainage Basin							
Basin A	--	--	9.0	12.0	--	--	--

* Partial Month
NR No Record
-- Mean Daily Discharge = 0

Table 5.1-2 Ratio of Instantaneous Maximum Discharge to Mean Daily Discharge

	Oct. '88	Apr. '89	May '89	June '89	July '89	Aug. '89	Sept. '89
			(dimensionless)				
<u>Irondale Gulch Drainage Basin</u>							
Havana Interceptor	2.2	11.5*	57.9*	378.4	524.3	98.8	88.6
Peoria Interceptor	8.7	22.2*	41.0	37.5	87.9	75.0	28.0
Ladora Weir	23.0	NR	--	--	12.7	1.6	1.5
South Uvalda	2.2	53.1*	94.4	91.7	117.6	152.0	122.0
North Uvalda	1.1	NR	100.9	48.4	--	2.7	1.2
Highline Lateral	34.1	--	3.7	22.8	--	21.7	10.9
South Plants Ditch	--	--	--	180.0	--	--	--
<u>First Creek Drainage Basin</u>							
South First Creek	NR	2.2*	7.3	3.9	23.8	18.0	--
North First Creek	NR	2.1*	5.8	6.2	--	--	--
First Creek Off-Post	NR	NR	NR	NR	4.0	--	NR
<u>South Platte Drainage Basin</u>							
Basin A	--	--	45.0	52.0	--	--	--

* Partial Month
NR No Record
-- Mean Daily Discharge = 0

SWAR89-5.TBL

Table 5.1-3 Evaporation, Precipitation, Lake Stage and Sewage Treatment Plant Discharge Data

		Climatic		Lake and Pond Stages[3]					
Month	Water Year	Total Precip.[1] (inches)	Total Evap.[2] (inches)	Upper Derby (feet)	Lower Derby (feet)	Ladora Lake (feet)	Lake Mary (feet)	Havana Pond (feet)	Sewage Treatment Plant Discharge (total gal.)
10/85	WY86	0.77	2.73	2.2	16.9	11.8	1.12	3.10	387,400
11/85		1.20	1.89	1.8	16.4	12.3	0.95	2.01	309,500
12/85		0.66	0.63	1.4	16.3	12.5	1.38	0.35	206,000
01/86		0.22	0.49	1.4	16.0	12.4	1.54	0	188,400
02/86		0.65	0.63	1.1	15.8	12.5	1.61	0	95,000
03/86		0.43	1.12	0.6	15.7	12.5	1.59	0	164,600
04/86		2.59	2.24	0	15.3	12.4	1.48	0	447,700
05/86		1.30	3.50	0.8	16.2	12.4	1.56	0.70	602,300
06/86		1.07	5.75	0	16.0	12.3	1.39	1.38	507,100
07/86		1.69	6.15	0	15.4	11.9	1.02	1.43	386,700
08/86		0.53	5.45	0	16.4	11.6	0.67	2.07	266,100
09/86		0.43	4.46	0	15.1	11.5	0.35	1.75	182,400
WY Total		11.54	35.04						3,743,500
10/86	WY87	1.29	2.73	0	15.8	11.85	0.09	1.39	297,200
11/86		1.05	1.89	0	15.4	11.9	0.21	3.01	446,400
12/86		0.31	0.63	0	15.0	12.2	0.45	1.07	534,300
01/87		0.68	0.49	0	14.7	12.3	0.45	0.40	240,400
02/87		1.21	0.63	0	14.4	12.3	0.60	0.82	205,300
03/87		1.34	1.12	0	14.3	12.4	0.83	1.33	309,500
04/87		1.03	2.24	0	14.2	12.4	0.96	1.44	400,400
05/87		4.64	3.50	0	14.2	12.3	0.91	1.60	338,000
06/87		3.42	6.68	0	14.4	12.3	0.80	3.31	128,400
07/87		0.76	6.78	1.3	16.9	12.4	1.00	4.33	327,600
08/87		2.00	5.63	0	16.1	12.0	1.25	2.57	387,200
09/87		0.70	6.20	0	15.9	11.7	0.96	2.87	295,500
WY Total		18.43	38.52						3,910,200

1 Precipitation values are recorded from Stapleton International Airport.
2 Evaporation values are based on pan evaporation data from Cherry Creek Reservoir.
3 Lake and pond stage data represent average monthly values.
NR Not recorded.

Note: A 0 stage value for Upper Derby Lake or Havana Pond indicates that the water level was below the staff gage or the lake or pond was dry.

Table 5.1-3 Evaporation, Precipitation, Lake Stage and Sewage Treatment Plant Discharge Data (continued)

		Climatic		Lake and Pond Stages[3]					
Month	Water Year	Total Precip.[1] (inches)	Total Evap.[2] (inches)	Upper Derby (feet)	Lower Derby (feet)	Ladora Lake (feet)	Lake Mary (feet)	Havana Pond (feet)	Sewage Treatment Plant Discharge (total gal.)
10/87	WY88	1.24	3.60	0	15.3	11.6	0.67	1.89	266,500
11/87		1.62	1.89	0	14.7	11.7	0.52	2.72	231,000
12/87		1.30	0.63	0	14.6	12.0	0.62	2.15	335,500
01/88		0.40	0.49	NR	NR	NR	NR	NR	374,200
02/88		0.60	0.63	NR	NR	NR	NR	NR	528,200
03/88		1.28	1.12	NR	NR	NR	NR	NR	573,400
04/88		0.65	2.24	0	13.79	12.20	1.33	1.23	571,000
05/88		4.26	3.50	2.83	14.28	12.17	1.18	3.29	643,000
06/88		1.28	5.75	6.98	14.13	12.42	0.97	2.88	556,200
07/88		2.19	5.48	4.77	16.48	12.15	1.07	2.46	510,500
08/88		1.83	5.81	5.30	16.72	11.96	0.65	2.75	696,500
09/88		0.90	4.62	5.18	16.88	11.74	0.28	2.39	633,100
WY Total		17.55	35.76						5,919,100
10/88	WY89	0.06	4.80	6.65	16.88	12.05	0.16	1.82	438,600
11/88		0.47	2.70	5.22	16.45	12.16	0.30	0	452,000
12/88		1.04	0.90	NR	NR	NR	NR	NR	400,900
01/89		1.14	0.70	NR	NR	NR	NR	NR	446,800
02/89		0.66	0.90	NR	15.78	12.35	0.83	0	264,800
03/89		0.56	1.60	0	15.90	12.27	1.02	0	340,000
04/89		1.00	3.20	1.03	15.70	12.20	0.86	1.69	118,400
05/89		3.83	6.80	3.22	15.26	12.12	0.62	2.76	334,000
06/89		2.04	6.94	6.80	16.06	12.08	0.60	3.16	377,900
07/89		1.64	9.98	5.38	15.12	11.85	0.71	2.13	652,100
08/89		1.28	7.64	5.05	13.66	11.98	0.72	15.19	862,400
09/89		1.55	6.80	4.40	12.75	11.33	0.77	2.47	583,500
		15.27	52.96						5,271,400

1 Precipitation values are recorded from Stapleton International Airport.
2 Evaporation values are based on pan evaporation data from Cherry Creek Reservoir.
3 Lake and pond stage data represent average monthly values.
NR Not recorded.

Note: A 0 stage value for Upper Derby Lake or Havana Pond indicates that the water level was below the staff gage or the lake or pond was dry.

then starting in June the stage gradually decreased from 16.30 ft on June 6 to 12.60 (5242.77 ft-msl) on September 26. The storage volume on September 26 was 278.44 ac-ft, 282.90 ac-ft less than the maximum stage measured at the beginning of the water year (16.90 ft).

5.1.2.3 Ladora Lake. Consistent with the historical record, the Ladora Lake stage varied by only about one ft during Water Year 1989. The stages varied between a high of 12.40 ft on February 22 (5219.51 ft-msl) to a low of 11.30 ft on September 12 and 26 (5218.41 ft-msl). The stage of Ladora Lake is maintained at a relatively constant level in order to meet the process water needs at RMA.

5.1.2.4 Lake Mary. The measured stages of Lake Mary during Water Year 1989 were consistent with the historical record, varying between a low of 0.12 ft on October 25 (5202.51 ft-msl) to a high of 1.08 ft on February 28 (5203.47 ft-msl). No stage/volume relationship is available for Lake Mary.

5.1.2.5 Havana Pond. The measured stages in Havana Pond during Water Year 1989 were consistent with the historical record. The stage varied between below gage 0 (5244.08 ft-msl) during February and March to a maximum of 4.81 ft (5248.89 ft-msl) measured on May 16. The maximum stage represents a storage volume of 78.26 ac-ft. This maximum occurred after a three-day rain period, May 13, 14 and 15, which totaled 2.02 in at Stapleton Airport.

5.1.3 Evaporation and Precipitation Data

Monthly evaporation and precipitation data for Water Years 1986, 1987, 1988 and 1989 are presented in Table 5.1-3. Evaporation measured during Water Year 1989 was substantially higher than the previous three years (52.96 in vs. 25.04, 38.52 and 35.76 in). The major increases were in October 1988 and July and August of 1989.

Precipitation during Water Year 1989 was near the 30-year normal. However, the precipitation during the first seven months was below normal reaching a total deficiency of 4.87 in by the end of April. Above normal precipitation during the last five months of the water year resulted in a total slightly above normal.

5.2 Surface-Water Quality Assessment

This section provides an assessment of trends from Water Year 1989 surface-water and stream-bottom sediment quality results, as presented in Sections 4.2 and 4.3. The discussion utilizes and compares historical surface-water data presented in Section 1.3.2.6 of this report along with the assessment presented in the Surface-Water CMP FY88 Annual Report to identify spatial and temporal trends in water quality during the reporting period. Contamination is assessed on the basis of interpreted upstream baseline conditions and the historical distribution of detected compounds. When possible, an attempt is made to examine relationships between concentration and discharge. In Section 6.0 of this report, the trends identified in this section are related to potential RMA and off-post source areas.

Mechanisms for the distribution and concentrations of chemical constituents in surface water and stream sediments are diverse and can complicate interpretation of data. Concentrations of chemical constituents can vary both spatially and temporally.

Spatial variations in concentrations of chemical constituents can occur on a large scale as the result of varying physical factors along a stream reach and on a small scale within a channel cross section as a function of depth and flow velocity. Factors affecting large-scale spatial variations in concentrations of organic constituents include proximity to contaminant source areas and chemical degradation/transformation as a function of exposure to sunlight and biological mechanisms.

Temporal variations in concentrations of chemical constituents at a given location can occur as a function of discharge, bed load transport, changes in base-flow chemistry, deposition of sediment particulates in the channel and/or washing of these particulates into the reach during storm events and seasonal environmental fluctuations (e.g., temperature).

Two idealized relationships between concentrations of chemical constituents and stream discharge are shown in Figures 5.2-1 and 5.2-2. Figure 5.2-1 represents physical conditions that produce a direct relationship between concentration and discharge. This situation would exist in cases in which a constituent having a constant or negligible base-flow concentration becomes elevated as the result of overland flow of the constituent into surface water during storm events. This relationship has been demonstrated in other studies in the U.S. in situations representing nonpoint-source runoff (e.g., gasoline and petroleum products washing from city streets to surface water during storm events). In such cases, concentrations of given constituents at a sampling location can be transient, and chemical constituents can be introduced into the channel in either dissolved and/or particulate form. The second idealized relationship, shown in Figure 5.5-2, represents physical conditions that produce an inverse relationship between concentrations and discharge. This situation would exist in cases in which a constituent having a relatively constant base-flow concentration is diluted by surface runoff having a lower or negligible concentration of that constituent.

A third physical condition affecting concentrations (not depicted) would involve windblown deposition of particulates directly into the channel, causing fluctuations in chemical concentrations independent of discharge.

With respect to data assessment, surface water must be considered a dynamic system capable of producing wide fluctuations in concentrations of chemical constituents, both temporally and spatially. Current data often must be assessed in concert with corresponding discharge data as well as historical chemical/discharge data to recognize the physical and chemical mechanisms influencing contaminant detections and basic water chemistry at a given location.

For inorganic constituents, water-quality baseline levels are defined as concentrations in water entering RMA that may represent naturally occurring conditions and/or anthropogenic influences. In contrast with inorganic constituents, baseline levels of organic constituents are zero in natural waters, and any detection must therefore be assessed with respect to potential anthropogenic sources. Elevated concentrations are defined as concentrations that are elevated with respect to water-quality baseline levels.

For the purposes of clarity and consistency, the water-quality assessment will be discussed according to the major drainage basins as described in previous sections of this report. The drainage basins include the First Creek drainage basin (Section 5.2.1), Irondale Gulch drainage basin (Section 5.2.2), South Platte drainage basin (Section 5.2.3) and Sand Creek drainage basin (Section 5.2.4). Conclusions are discussed in Section 6.0.

5.2.1 First Creek Drainage Basin

Surface-water CMP locations sampled in the First Creek drainage basin during FY89 are:

SW08001	South First Creek Boundary
SW08003	South First Creek monitoring station
SW24001	Sewage Treatment Plant
SW24002	North First Creek monitoring station
SW24003	North Bog
SW24004	First Creek North Boundary
SW30001	North Plants
SW30002	First Creek near North Plants
SW31001	First Creek Toxic Yard A

SW31002 First Creek Toxic Yard B

SW37001 First Creek Off-Post monitoring station

These locations are shown on Plate 1.3-2.

5.2.1.1 Organic Compounds in Surface Water. Samples collected from 7 of the 11 First Creek drainage basin surface-water sampling locations during FY89 contained detectable concentrations of organic compounds (Plate 4.2-1 and Table 4.2-3). Vapona was the compound most frequently detected during FY89 and was detected in samples from four locations during the spring sampling event: South First Creek Boundary (SW08001), First Creek near North Plants (SW30002), North First Creek monitoring station (SW24002) and North Bog (SW24003). Historical data presented in Table 1.3-9 indicate that Vapona has historically not been detected at these locations. However, Vapona was not a target compound prior to FY89, and it is unlikely that analyses for Vapona were historically performed.

A sample collected at South First Creek monitoring station (SW08003) during a storm event contained DBCP. Samples collected from this location during the fall sampling event also contained dieldrin and endrin. Organic compounds were not detected in samples collected from this location during the spring sampling event or historical events.

DMMP was detected in a sample collected at the Sewage Treatment Plant (SW24001) during the fall sampling event. Historical data presented in Table 1.3-9 indicate that DMMP has historically not been detected in samples from this location. However, the CRL for DMMP was 29.3 μg/l in 1988 and 0.188 μg/l in 1989. The difference in CRLs relates to two separate laboratories used for the analysis of phosphonates. DMMP was not detected in samples collected at this location during the spring sampling event.

DIMP was detected in samples collected at the North Bog (SW24003) and First Creek Off-Post monitoring station (SW37001) during the spring sampling event. Historical data presented in Table 1.3-9 indicate that DIMP has been detected at the North Bog in 14 of 25 samples and at First Creek Off-Post monitoring station in 20 of 20 samples. During the FY88 CMP sampling events, DIMP was detected in a sample from First Creek Off-Post monitoring station (SW37001) but not in a sample from North Bog (SW24003). However, the CRL for DIMP in FY88 was 18.5 μg/l and currently is 0.392 μg/l.

In addition to DIMP, a sample collected at First Creek Off-Post monitoring station (SW37001) during the spring sampling event contained atrazine, chlordane, DCPD, dieldrin, endrin and

PPDDT. Historical data presented in Table 1.3-9 indicate that only DCPD and dieldrin have been detected in samples collected at this location in the past. However, of the remaining compounds not historically detected, atrazine was not included in historical target compound lists.

5.2.1.2 Inorganic Constituents in Surface Water. First Creek enters RMA along the southeastern boundary of Section 8 near surface-water sampling location SW08001. Inorganic constituent results for this location from the spring sampling events for both FY88 and FY89 CMP were compiled to establish a range of concentrations considered to be representative of water-quality baseline levels during base-flow conditions. Base flow data for this site was established by daily discharge data obtained from nearby South First Creek monitoring station (SW08003). Samples were not collected from SW08001 during any storm event; therefore, water-quality baseline levels for elevated flow conditions could not be established. The water-quality baseline levels for trace and major inorganic metals are further separated into total and dissolved fractions and are presented in Table 5.2-1.

Detected concentrations of inorganic constituents in samples from downstream locations were compared with the water-quality baseline levels established for SW08001. Samples collected during the spring and fall sampling events are considered to be representative of base-flow conditions. Although water-quality baseline levels for elevated flow conditions have not been established, analytical results for samples collected during storm events were included in the comparison with water-quality baseline levels established for base flow conditions. Eight samples collected during the spring sampling event, one sample collected during a storm event, and two samples collected during the fall sampling event had reported concentrations of inorganic constituents that were above water-quality baseline levels. The elevated concentrations and associated sampling locations are presented in Table 5.2-2. This table includes only values for the inorganic constituents that exceeded established water-quality baseline levels listed in Table 5.2-1.

Three samples collected during the spring and fall sampling events contained elevated concentrations of calcium. The three sampling locations are First Creek near North Plants (SW30002; spring), North Bog (SW24003; spring) and South First Creek monitoring station (SW08003; fall).

The dissolved and/or total fractions of magnesium, potassium and sodium were detected above water-quality baseline levels in the majority of the samples collected during the spring sampling event. One filtered sample collected at North First Creek monitoring station (SW24002) during a storm event contained elevated concentrations of magnesium, potassium and sodium. An unfiltered sample collected from the Sewage Treatment Plant (SW24001) during the fall sampling

Table 5.2-1 Baseline Surface-Water Quality Levels for Inorganic Constituents Entering RMA in the First Creek Drainage Basin at First Creek South Boundary (SW08001) during Base Flow Conditions

Analyte	Dissolved Fraction Concentrations	Total Recoverable Concentrations	Units
Calcium	80.1 - 91.3	82.0 - 92.1	mg/l
Chloride	32.0 - 35.0	NA	mg/l
Fluoride	1.10 - 1.22	NA	mg/l
Potassium	3.78 - 3.85	3.84 - 4.05	mg/l
Magnesium	17.3 - 19.5	17.5 - 19.7	mg/l
Sodium	56.2 - 62.9	58.1 - 63.2	mg/l
Nitrate	0.450 - 1.28	NA	mg/l
Sulfate	90.0 - 98.0	NA	mg/l
Arsenic	<2.50 - 2.61	<2.35 - 3.23	µg/l
Cadmium	<8.40	<8.40	µg/l
Chromium	<24.0	<24.0	µg/l
Copper	<26.0	<26.0	µg/l
Mercury	<0.100	<0.100	µg/l
Lead	<74.0	<74.0	µg/l
Zinc	<22.0	<22.0	µg/l

Note: Data incorporated from sampling location SW08001 for FY88 CMP and FY89 CMP

mg/l = milligrams per liter

µg/l = micrograms per liter

< = less than CRL

NA = not applicable

Table 5.2-2 Elevated Inorganic Constituent Concentrations for First Creek Drainage Basin Sites for FY89 CMP[1]

Sampling Location	Sampling Period	Calcium mg/l	Magnesium mg/l	Potassium mg/l	Sodium mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate mg/l	Arsenic µg/l
SW24001	Spring			4.79_D	76.0_D	47.0			19.5	29.0_D
SW24002	Spring		28.2_T 29.3_D	3.94_D	120_T 130_D	54.0	1.63	230		
SW24003	Spring	110_T 110_D	62.4_T 63.5_D		260_T 250_D	240	2.37	450		
SW24004	Spring		30.4_T 30.9_D	4.15_T 4.00_D	130_T 130_D	55.0	1.50	240		
SW30002	Spring	92.6_D	27.8_T 30.2_D	4.18_D	110_T 120_D	52.0	1.55	190	3.32	
SW31001	Spring		30.4_T 27.9_D		94.8_T 97.4_D	44.0	1.95	130	23.0	
SW31002	Spring		24.8_T 23.9_D	4.48_T 4.37_D	89.6_T 90.3_D	44.0	1.39	150		
SW37001	Spring		40.4_T 41.7_D	4.44_T 4.66_D	210_T 210_D	130	2.05	320		
SW24002	Storm		25.0_D	6.44_D	88.9_D	48.0	1.35	150		
SW08003	Fall	113_T	23.7_T	4.35_T	76.0_T	52.0		150		
SW24001	Fall			5.29_T		55.0	1.33		8.86	30.2_T

[1] Concentrations are elevated with respect to establish baseline surface-water quality levels listed in Table 5.2-1

$_D$ = Dissolved fraction concentrations

$_T$ = Total Recoverable concentrations

mg/l = milligrams per liter

µg/l = micrograms per liter

SWR89-5L.TBL

event contained elevated concentrations of potassium, and an unfiltered sample collected at South First Creek monitoring station (SW08003) during the fall sampling event contained elevated concentrations of magnesium, potassium and sodium.

Elevated levels of chloride were detected in eight samples collected during the spring sampling event. A sample collected at North First Creek monitoring station (SW24002) during a storm event and at South First Creek monitoring station (SW08003) and the Sewage Treatment Plant (SW24001) during the fall sampling event also contained elevated concentrations of chloride.

Sulfate and fluoride were each detected at elevated concentrations in seven samples collected during the spring sampling event. A sample collected at North First Creek monitoring station (SW24002) during a storm event contained elevated concentrations of fluoride and sulfate. A sample collected at South First Creek monitoring station (SW08003) and the Sewage Treatment Plant (SW24001) during the fall sampling event contained elevated concentrations of sulfate and fluoride, respectively.

Elevated levels of nitrate were detected in three downstream samples from First Creek Toxic Yard A (SW31001; spring), First Creek Near North Plants (SW30002; spring) and the Sewage Treatment Plant (SW24001; spring and fall).

Arsenic was the only trace metal with reported elevated concentrations. These detections were reported for two samples collected from the Sewage Treatment Plant (SW24001) during the spring and fall sampling events. Historical detections of arsenic have been reported for samples collected from this location in five of six sampling events, as shown in Table 1.3-10.

5.2.1.3 Organic Compounds in Stream-Bottom Sediments. Stream-bottom sediment samples were collected at the First Creek drainage basin locations SW08001, SW08003, SW24002, SW30002, SW31002 and SW37001 during FY89. Although six organic compounds were detected in stream-bottom sediment samples, only atrazine and CPMSO were detected at two or more locations. Additionally, sediment target organic compound detections were generally not directly related to surface-water detections. Atrazine was detected in stream-bottom sediment samples from all locations except North First Creek monitoring station (SW24002). The only surface-water detection of atrazine was at First Creek Off-Post monitoring station (SW37001). CPMSO was detected in sediment samples from SW08001 and SW30002 but was not detected in surface-water samples from these locations. Dieldrin was detected in sediment samples collected from SW08003 and SW31001, but was only detected in a surface-water sample collected during the same sampling event.

5.2.1.4 Trace Metals in Stream-Bottom Sediments. The occurrence of trace metals in samples from the stream-bottom sediment along First Creek was limited to detections at five locations. Chromium, copper, lead and zinc were detected most frequently in the sediment samples.

Zinc was the only trace metal detected in a sample from South First Creek Boundary (SW08001; 22.4 $\mu g/g$). Zinc was also detected at elevated concentrations relative to 22.4 $\mu g/g$ at North First Creek monitoring station (SW24002), First Creek Toxic Yard A (SW31001), First Creek Toxic Yard B (SW31002) and First Creek Off-Post monitoring station (SW37001).

Chromium, copper and lead were detected in downstream samples. Chromium was detected in samples from SW24002, SW31001 and SW31002. Copper was detected in samples from SW31001, SW31002 and SW37001. Lead was detected in samples from SW24002 and SW31002.

The detections of trace metals in stream-bottom sediment samples do not correlate with trace metals detected in surface-water samples collected along First Creek. Arsenic was the trace metal detected most frequently in surface-water samples, and zinc was the trace metal detected most frequently in stream-bottom sediment samples.

5.2.2 Irondale Gulch Drainage Basin

Surface-water CMP locations sampled in the Irondale Gulch drainage basin during FY89 are:

SW01001 North Uvalda monitoring station
SW01002 South Plants water tower pond
SW01004 Upper Derby Lake
SW01005 Lower Derby Lake
SW02003 Ladora Lake
SW02004 Lake Mary
SW02006 South Plants steam effluent
SW07001 Uvalda Ditch A
SW07002 Uvalda Ditch B
SW11001 Peoria Interceptor monitoring station
SW11002 Havana Interceptor monitoring station
SW11003 Havana Pond
SW12001 Uvalda Ditch C
SW12002 Uvalda Ditch D

SW12003 Rod and Gun Club Pond

SW12004 Storm Sewer

SW12005 South Uvalda monitoring station

5.2.2.1 Organic Compounds in Surface Water. Target organic compounds detected in surface water entering RMA at the southern boundary during FY89 sampling events include the organochlorine pesticides; aldrin, chlordane, dieldrin, isodrin, CL6CP, PPDDE and PPDDT; the organophosphorus compounds atrazine, parathion and Vapona; the phosphonates DIMP and DMMP; and CPMSO, xylenes (o,p), 4-methylphenol and 2,4,5-trichlorophenol. The distribution of these detections is shown on Plate 4.2-1.

Organochlorine pesticides were the most frequently detected surface-water contaminants at the southern boundary locations. CL6CP was detected in samples collected from Uvalda Ditch A (SW07001), Peoria Interceptor monitoring station (SW11001) and Havana Interceptor monitoring station (SW11002) during the spring sampling event. However, CL6CP was not detected in samples collected at these three locations during the fall event or in samples collected at Peoria Interceptor monitoring station and Havana Interceptor monitoring station (SW11001 and SW11002, respectively) during storm events. The FY88 CMP sampling results presented in Table 1.3-4 indicate that CL6CP was detected in a sample collected at Havana Interceptor monitoring station (SW11002) only during a FY88 storm event and that it was not detected during two FY88 sampling events at Uvalda Ditch A (SW07001) or four sampling events at the Peoria Interceptor monitoring station (SW11001). CL6CP was, however, detected in FY88 in samples from Havana Pond (SW11003) and South Uvalda monitoring station (SW12005).

The organochlorine pesticides aldrin and PPDDT were detected at the southern RMA boundary in samples collected at Uvalda Ditch A (SW07001) and Havana Pond (SW11003) during the spring sampling event. Historical data presented in Table 1.3-9 indicate that organochlorine pesticides have not historically been detected at these locations. Additional organochlorine pesticide detections during the spring sampling event include dieldrin, isodrin and PPDDE at Uvalda Ditch A (SW07001) and chlordane at Havana Pond (SW11003). There were no detections at Uvalda Ditch A (SW07001) during the fall event.

Organophosphorus compounds were detected in surface-water samples from four locations along the southern RMA boundary. Vapona was detected in samples collected from Uvalda Ditch A (SW07001) and Havana Pond (SW11003) during the spring sampling event and in a sample collected from the Storm Sewer (SW12004) during the fall sampling event. Atrazine was also detected in a sample collected from the Storm Sewer (SW12004) during the fall sampling event. Parathion was detected in a sample collected at the Peoria Interceptor monitoring station (SW11001) during a storm event. With the exception of Havana Pond (SW11003), these locations were sampled more than once during FY89, but detections were reported for only one of the events. Historically, these organophosphorus compounds were not included in the CMP surface-water target parameter list.

The phosphonates DIMP and DMMP were detected in surface-water samples from two locations along the southern RMA boundary. DMMP was detected in a sample collected from Uvalda Ditch A (SW07001) during the spring sampling event, and DIMP was detected in a sample collected from Uvalda Ditch B (SW07002) during the fall sampling event. Historical data presented in Table 1.3-9 indicate that the only historical phosphonate compound detection at these locations was one detection of DIMP in 25 samples from Uvalda Ditch B (SW07002). It should be noted, however, that the CRLs for DIMP and DMMP in FY89 were approximately two orders of magnitude lower than historical CRLs, as discussed in Section 5.2.1.1.

Additional contaminants detected near the RMA southern boundary during FY89 surface-water sampling events include CPMSO and 4-methylphenol in a sample collected from the Storm Sewer (SW12004) during the spring sampling event and xylenes (o,p) and 2,4,5-trichlorophenol in a sample collected at the Peoria Interceptor monitoring station (SW11001) during a storm event. Historical data (Table 1.3-9) indicate that these compounds have not been detected at these locations in the past; however, phenols were not included in the target parameter list of historical monitoring programs.

In general, organic compounds detected in surface-water entering the southern RMA boundary in FY89 were both low in concentration and inconsistent in spatial and temporal occurrence. Contaminants detected in surface-water samples from Uvalda Ditch A (SW07001) and Uvalda Ditch B (SW07002) have not been detected at downstream locations Uvalda Ditch D (SW12001) and South Uvalda monitoring station (SW12005) in either FY89 or historical sampling events. Similarly, contaminants detected in surface-water samples collected from the Havana Interceptor monitoring station and Peoria Interceptor monitoring station (SW11001 and SW11002, respectively) in FY89 are different from the contaminants detected in downstream surface-water samples from Havana Pond (SW11003).

Four of six surface-water samples collected from sampling locations in the South Plants Lakes area in FY89 contained organic contaminants (Plate 4.2-1). Endrin was detected in samples collected from the Rod and Gun Club Pond (SW12003) and Upper Derby Lake (SW01004) during the spring sampling event. Isodrin was detected in samples collected from Lake Mary (SW02004) during the spring sampling event. DMMP was detected in a sample collected at North Uvalda monitoring station (SW01001) during the spring sampling event; however, organic contaminants were not detected in a sample collected at this location during the fall sampling event. Organic contaminants were not detected in surface-water samples collected from Lower Derby Lake (SW01005) and Ladora Lake (SW02003) in FY89. Contaminants detected in samples collected from the South Plants Lakes area in FY89 were generally low in concentrations.

Historical sampling data presented in Table 1.3-9 indicate that the contaminants detected in surface-water samples collected from the South Plants Lakes area in FY89 have not been detected in samples collected from these locations in the past. Table 1.3-9 indicates that CHCL3 has been detected in six of eight samples from Ladora Lake (SW02003); however, CHCL3 has not been detected in samples collected during the CMP.

The remaining surface-water quality sampling locations in the Irondale Gulch drainage basin are in the South Plants area. These locations are the South Plants water tower pond (SW01002) and the South Plants steam effluent (SW02006). A sample collected from the South Plants water tower pond (SW02006) during the spring sampling event contained 20 target organic compounds. Samples collected from the South Plants steam effluent (SW02006) during both the spring and fall sampling events contained CHCL3, and samples from the same location during the spring sampling event contained DMMP. Historical data presented in Table 1.3-9 indicate generally similar detections of compounds at these locations in the past. However, the organophosphorus compounds atrazine, malathion, parathion, Supona and Vapona were not historically included in the surface-water target parameter list at RMA. Most of these organophosphorus compounds were detected at the South Plants water tower pond (SW01002) in FY89.

5.2.2.2 <u>Inorganic Constituents in Surface Water</u>. Inorganic constituent data for samples collected from sampling locations SW07001, SW07002, SW11001, SW11002, SW11003, SW12001, SW12002 and SW12005 during both FY88 and FY89 CMP were utilized to establish representative inorganic water-quality baseline levels for the Irondale Gulch drainage basin. These water-quality baseline levels were separated according to flow conditions. Analytical results for samples collected during the spring and fall sampling events were utilized to establish water-quality baseline levels for base-flow conditions, and analytical results for samples collected during the storm events were utilized to establish water-quality baseline levels for elevated flow conditions. Water-quality baseline levels for base flow were established for both the total and dissolved fraction for the trace metals and major inorganic analytes. Water-quality baseline levels for elevated flow conditions were established from the FY88 and FY89 CMP data for the dissolved fraction. Total recoverable analyses were not conducted on samples collected during the FY89 storm events; therefore, the FY88 data were utilized in establishing water-quality baseline levels for elevated flow conditions for total recoverable concentrations. The water-quality baseline levels of the total and dissolved fractions are presented in Table 5.2-3.

Detected concentrations of inorganic constituents at downstream locations were compared with the water-quality baseline levels established for the Irondale Gulch drainage basin. The elevated concentrations and associated sampling locations are listed in Table 5.2-4. This table includes only values for the inorganic constituents that exceeded the water-quality baseline levels listed in Table 5.2-3. Elevated concentrations of dissolved and total calcium, magnesium and potassium were detected in a sample collected from the Rod and Gun Club Pond (SW12003) during the spring sampling event. The concentrations of the total and dissolved fractions for the analytes detected in samples from this location were comparable (Table 5.2-4).

Elevated concentrations of sulfate were reported for a sample collected from the Rod and Gun Club Pond (SW12003) during the spring sampling event.

Arsenic and mercury were the only trace metals detected above baseline levels. Arsenic was detected at elevated concentrations in a sample collected from the South Plants water tower pond (SW01002), Upper Derby Lake (SW01004) and the Rod and Gun Club Pond (SW12003) during the spring sampling event. Historical detections of arsenic have been reported only for samples from the South Plants water tower pond (SW01002).

Mercury was detected at elevated concentrations in a sample collected from the South Plants water tower pond (SW01002) and the South Plants steam effluent (SW02006) during the spring sampling event. A sample collected from the South Plants steam effluent (SW02006) during the fall sampling event also contained mercury at elevated concentrations. Historical detections of mercury have been reported for samples from the South Plants water tower pond (SW01002) and the South Plants steam effluent (SW02006).

5.2.2.3 Organic Compounds in Stream-Bottom Sediments. Stream-bottom sediment samples were collected from 9 of 17 locations within the Irondale Gulch drainage basin during the spring sampling event. Sediment samples were collected from locations SW01001, SW01002, SW02006, SW07001, SW11001, SW11002, SW12003, SW12004 and SW12005.

Although organochlorine pesticides were detected in several surface-water samples collected during the spring sampling event, they were not detected in stream-bottom sediment samples collected at the southern RMA boundary during FY89.

Table 5.2-3 Baseline Surface-Water Quality Levels for Inorganic Constituents Entering RMA in the Irondale Gulch Drainage Basin During Base and Elevated Flow Conditions

	Dissolved Fraction Concentrations		Total Recoverable Concentrations		
Analyte	Base Flow	Elevated Flow	Base Flow	Elevated Flow	Units
Calcium	14.2 - 75.8	2.00 - 14.3	14.7 - 80.3	6.32 - 17.5	mg/l
Chloride	4.85 - 140	0.740 - 18.1	NA	NA	mg/l
Fluoride	0.484 - 2.14	<0.482 - 1.22	NA	NA	mg/l
Potassium	1.80 - 7.98	1.47 - 5.05	1.93 - 8.24	2.74 - 1.97	mg/l
Magnesium	1.71 - 29.8	0.400 - 4.19	1.91 - 34.2	0.931 - 5.33	mg/l
Sodium	6.47 - 140	2.14 - 13.2	6.89 - 130	2.38 - 16.0	mg/l
Nitrate	0.093 - 19.0	2.04 - 7.08	NA	NA	mg/l
Sulfate	17.0 - 210	2.49 - 24.4	NA	NA	mg/l
Arsenic	<2.35	<2.35	<2.35 - 2.64	4.74	µg/l
Cadmium	<8.40	<8.40	<8.40	--	µg/l
Chromium	<24.0	<22.0	<16.8	<24	µg/l
Copper	<26.0	<10.0 - 10.5	<18.8	<26	µg/l
Mercury	<0.100	<0.100	<0.100 - 0.229	<0.100	µg/l
Lead	<74.0	<52.0	<43.4	<74.0	µg/l
Zinc	<22.0 - 52.7	<22.0 - 122	<18.0 - 68.8	168 - 190	µg/l
Cyanide	--	--	<5.00 - 6.91	<2.50	µg/l

Note: Data incorporated from sites SW07001, SW07002, SW12001, SW12002, SW12005, SW11001, SW11002, and SW11003 for FY88 CMP and FY89 CMP
NA = Not applicable
-- = Data not available for FY88 CMP
mg/l = milligrams per liter
µg/l = micrograms per liter
< = less than CRL

Table 5.2-4 Elevated Inorganic Constituent Concentrations for Irondale Gulch Drainage Basin and South Platte Drainage Basin Sites[1] for FY89 CMP

Sampling Location	Sampling Period	Calcium mg/l	Magnesium mg/l	Potassium mg/l	Sodium mg/l	Fluoride mg/l	Sulfate mg/l	Arsenic µg/l	Mercury µg/l	Cadmium µg/l
Irondale Gulch Drainage Basin										
SW01002	Spring							16.9_D	0.200_D	
SW01004	Spring							2.44_D		
SW02006	Spring								0.100_D	
SW12003	Spring	100_T 110_D	45.5_T 42.5_D	12.0_T 12.0_D			240	3.11_T 2.77_D		
SW02006	Fall								0.294_T	
South Platte Drainage Basin										
SW36001	Spring				150_T 140_D	2.22		280_T 280_D		14.9_T 13.5_D
SW36001	Fall							118_T	0.236_T	86.0_T

1 Concentrations are elevated with respect to established baseline surface-water quality levels listed in Table 5.2-3.

$_D$ = Dissolved fraction concentrations

$_T$ = Total Recoverable concentrations

mg/l = milligrams per liter

µg/l = micrograms per liter

SWR89-5L.TBL

The organophosphorus compound atrazine was detected in stream-bottom sediment samples collected from five sampling locations near the southern RMA boundary during the spring sampling event (Plate 4.3-1): Uvalda Ditch A (SW07001), Peoria Interceptor monitoring station (SW11001), Havana Interceptor monitoring station (SW11002), the Storm Sewer (SW12004) and South Uvalda monitoring station (SW12005). Atrazine was not detected in surface-water samples collected at these locations during the spring sampling event. The only detection of atrazine in surface-water near the southern RMA boundary in FY89 was reported for a sample collected from the Storm Sewer (SW12004) during the fall sampling event.

DMMP was only detected in a stream-bottom sediment sample obtained at the South Uvalda monitoring station (SW12005) during the fall sampling event. There was not a corresponding detection in the surface-water sample from this location.

Vapona and parathion were detected in a stream-bottom sediment sample collected from the Storm Sewer (SW12004) during the spring sampling event. Vapona was also detected in a surface-water sample from this location, but the detection was reported during the fall sampling event.

CPMSO, DBCP, 111TCE and toluene were detected in stream-bottom sediment samples near the southern RMA boundary in FY89 (Plate 4.3-1). CPMSO was detected in stream-bottom sediment samples from four locations, and DBCP was detected in a stream-bottom sediment sample from one location near the southern RMA boundary, the Peoria Interceptor monitoring station (SW11001). Comparison of detections in sediment samples to detections in surface-water samples from southern RMA boundary locations indicates that CPMSO detected in a surface-water sample from the Storm Sewer (SW12004) is the only similar occurrence of these compounds between surface-water and stream-bottom sediment samples. Historical surface-water detections presented in Table 1.3-9 indicate that 111TCE has been detected in surface-water samples from the Peoria Interceptor monitoring station (SW11001) in 2 of 14 historical samples.

Stream-bottom sediment samples from the South Plants Lakes area contained atrazine and CMPSO. Atrazine was detected in a stream-bottom sediment sample from the North Uvalda monitoring station (SW01001). Atrazine and CPMSO were detected in a stream-bottom sediment sample from the Rod and Gun Club Pond (SW12003). In both cases, there was no corresponding occurrence of these compounds in surface-water samples from the South Plants Lakes area in FY89.

Stream-bottom sediment samples were collected from two South Plants area sampling locations in FY89. Most of the contaminants detected in stream-bottom sediment samples from the South Plants water tower pond (SW01002) were also detected in a surface-water sample from this location. At the South Plants steam effluent (SW02006), atrazine and DBCP were detected in a stream-bottom sediment sample collected during the spring sampling event, and aldrin, dieldrin, endrin, isodrin and BTZ was detected in a stream-bottom sediment sample collected during the fall sampling event. For this latter case, there were no corresponding detections of these compounds in surface-water samples from this location.

5.2.2.4 Trace Metals in Stream-Bottom Sediments. Analytical results for trace metals detected in stream-bottom sediment samples collected from four sampling locations (SW07001, SW11001, SW11002 and SW12005) during the spring sampling event have been integrated to establish sediment-quality baseline levels. The baseline for arsenic was established from the fall sampling event data. The sediment-quality baseline levels are listed in Table 5.2-5.

Detected concentrations of trace metals in samples from locations in the Irondale Gulch drainage basin were compared with the established sediment-quality baseline levels. Samples collected from three sampling locations (SW02006, SW12003 and SW12004) contained elevated concentrations of trace metals.

A stream-bottom sediment sample from the South Plants steam effluent (SW02006) contained elevated concentrations of chromium, copper, mercury, lead and zinc.

A stream-bottom sediment sample from the Rod and Gun Club Pond (SW12003) contained elevated concentrations of arsenic, cadmium, chromium, copper, lead and zinc.

A stream-bottom sediment sample from the Storm Sewer (SW12004) contained elevated concentrations of lead.

In general, the detections of trace metals in stream-bottom sediment samples do not correlate with detections of trace metals in surface-water samples from the Irondale Gulch drainage basin. Arsenic, mercury and zinc were the most frequently detected trace metals in surface-water samples, and the heavier trace metals (chromium, cadmium and lead) were detected most frequently in sediment samples.

5.2.3 South Platte Drainage Basin

The surface-water CMP location sampled in the South Platte drainage basin is:

SW36001 Basin A monitoring station

Table 5.2-5 Baseline Trace Metal Concentrations for Stream-Bottom Sediments in the Irondale Gulch Drainage Basin

Analyte	Concentration ($\mu g/g$)
Arsenic	1.23
Chromium	9.99
Copper	14.5 - 17.5
Lead	18.1 - 32.2
Zinc	63.4 - 102

Note: Data incorporated from samples collected from SW07001, SW11001, SW11002, and SW12005 during the FY89 spring sampling event

$\mu g/g$ = micrograms per gram

5.2.3.1 Organic Compounds in Surface Water. Samples collected from Basin A (SW36001) during the spring sampling event contained 37 target organic compounds, and samples collected during the fall sampling event contained 27 target organic compounds. Compared to samples collected during the spring sampling event, samples collected during the fall sampling event contained organic contaminants at generally much lower concentrations.

5.2.3.2 Inorganic Constituents in Surface Water. The concentrations of inorganic constituents detected in samples collected at the Basin A monitoring station (SW36001) were compared to the water-quality baseline levels established for the adjacent Irondale Gulch drainage basin listed in Table 5.2-3. Elevated concentrations are listed in Table 5.2-4. Elevated concentrations of dissolved and total sodium were detected in a sample collected during the spring sampling event.

Elevated concentrations of fluoride were detected in a sample collected during the spring sampling event. Arsenic, mercury and cadmium were the only trace metals detected above water-quality baseline levels. A sample collected during the spring and fall sampling events contained elevated concentrations of arsenic. Historical detections of arsenic have been reported for samples collected at the Basin A monitoring station (SW36001).

A sample collected during the fall sampling event contained mercury at elevated concentrations. Historical detections of mercury have apparently not been reported for samples from the Basin A sampling location (SW36001).

Cadmium was detected above water-quality baseline levels in a sample collected during the spring and fall sampling events. Historical detections of cadmium have apparently not been reported for samples collected at the Basin A monitoring station (SW36001).

5.2.3.3 Organic Compounds in Stream-Bottom Sediments. Nine organic compounds were detected in a stream-bottom sediment sample collected at the Basin A monitoring station (SW36001) during the spring sampling event. These nine compounds were also detected in a surface-water sample from this location but at higher concentrations. Four organic compounds were detected in a stream-bottom sediment sample collected from this location during the fall sampling event. These four compounds were also detected in a surface-water sample collected at this location at the same time but at lower concentrations.

5.2.3.4 Trace Metals in Stream-Bottom Sediments. Detected concentrations of trace metals in samples collected at the Basin A monitoring station (SW36001) were compared with the established sediment-quality baseline levels listed in Table 5.2-5.

A stream-bottom sediment sample collected at the Basin A monitoring station (SW36001) contained elevated concentrations of arsenic, cadmium, mercury and lead.

5.2.4 Sand Creek Drainage Basin

The surface-water CMP location sampled in the Sand Creek drainage basin is:

SW04001 Motor Pool

5.2.4.1 Organic Compounds in Surface Water. There was one detection of dieldrin in a surface-water sample collected during a storm event. Historical detections of organic compounds have apparently not been reported for samples from the Motor Pool (SW04001).

5.2.4.2 Inorganic Constituents in Surface Water. The concentrations of inorganic constituents detected in samples from the Motor Pool (SW04001) were compared to the water-quality baseline levels established from the adjacent Irondale Gulch drainage basin listed in Table 5.2-3. Elevated concentrations of inorganic constituents were not detected in samples from this location.

5.3 Ground-Water/Surface-Water Interaction Assessment

The data collected in the assessment of surface-water and ground-water interactions were presented in Section 4.4. The discussion of the assessment has been divided into sections for the First Creek drainage basin (5.3.1) and the South Plants Lakes area (5.3.2) within the Irondale Gulch drainage basin (5.3.3).

5.3.1 First Creek Drainage Basin

Data were assessed from monitoring wells and surface-water sampling locations in the First Creek drainage basin by comparing major ion chemistry data and organic compound detections at surface-water and ground-water sampling locations. From data collected in Section 31 on RMA, Stiff diagrams constructed from the analytical results for surface- and ground-water samples from Well 31016 and SW31001 (First Creek Toxic Yard A) indicate that these waters are characterized as sodium carbonate (Figure 4.2-1).

In Section 24, the Stiff diagram constructed from the analytical results for an alluvial ground-water sample from Well 24188 is different from Stiff diagrams constructed from the analytical results for surface-water samples collected in the vicinity of SW24002. Samples of ground water collected from this well contained high concentrations of sodium and sulfate. Upstream of this well, surface water is characterized as sodium carbonate, and downstream of this well, surface water is characterized as sodium sulfate. The RMA sewage treatment plant discharges to First Creek in the vicinity of Well 24188; however, analytical results for samples from this discharge water (SW24001) indicated relatively low concentrations of sodium and sulfate.

Alluvial ground water and surface water along First Creek north of RMA exhibit similar chemical characteristics. Stiff diagrams constructed from the analytical results for samples from Well 37343 and SW37001 (First Creek Off-Post monitoring station) exhibit waters characterized as sodium sulfate (Figure 4.4-1). In addition, the occurrence and concentrations of organic contaminants in samples from these sampling locations are similar (Table 4.4-1). The organic contaminants chlordane, DCPD, DIMP, dieldrin, endrin and PPDDT were detected in both surface- and ground-water samples collected from these sampling locations during the spring FY89 sampling events.

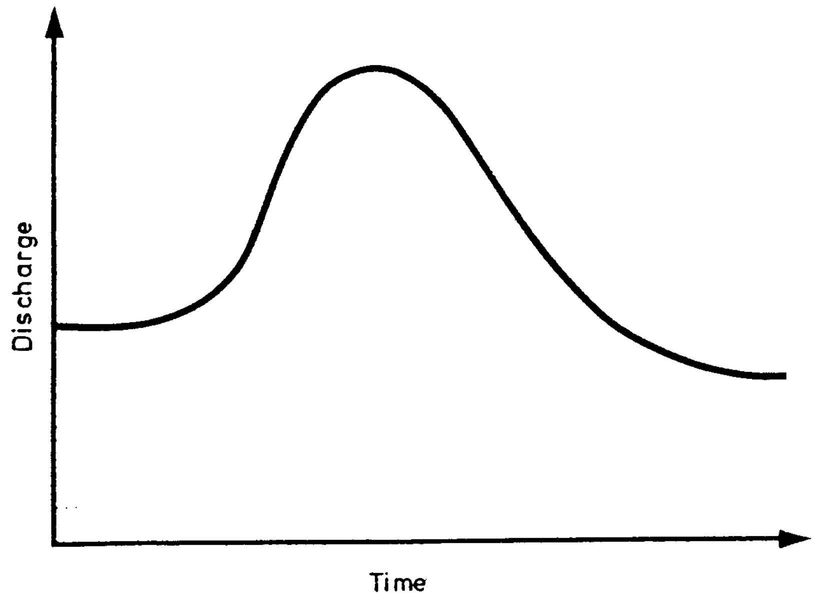
Due to the lack of sufficient monitoring wells located in close proximity to First Creek, a hydrographic analysis of ground-water and surface-water interaction could not be performed.

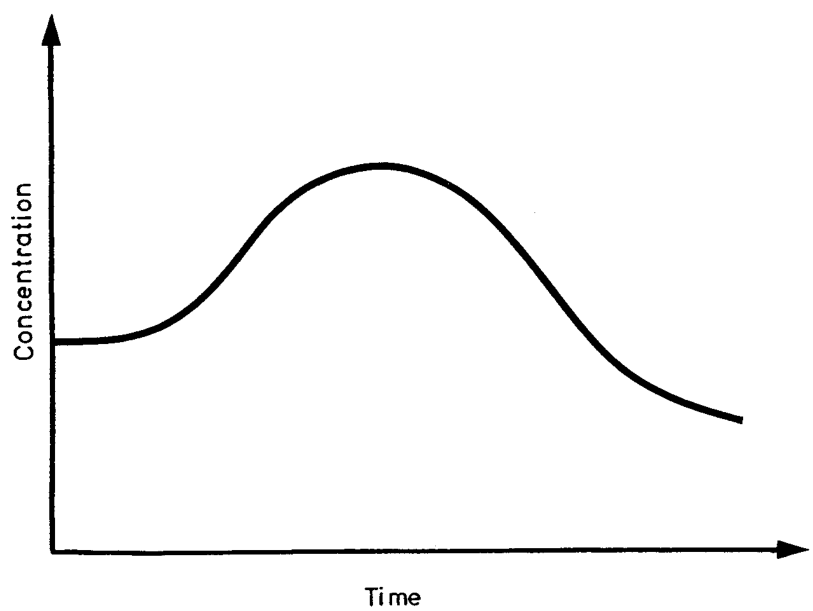
5.3.2 South Plants Lakes Area

From a comparison of the major ion chemistry and organic compounds detected in samples of surface water and ground water in the South Plants Lakes area, the surface water from Upper Derby Lake and Lower Derby Lake and ground water from Well 01074 are characterized as sodium/calcium carbonate. However, Denver Formation water from nearby Well 01047 and alluvial ground water from Well 01073 are characterized as sodium sulfate and sodium carbonate, respectively. A water sample from Well 02059, which appears to be downgradient of Lower Derby Lake, is characterized as calcium carbonate. Well 02060, screened in the Denver Formation at the same location as Well 02059, is characterized as sodium carbonate.

The water chemistry of samples from Ladora Lake and Lake Mary and upgradient Well 02034 exhibit similar characteristics. The water samples from these locations are characterized as sodium carbonate. However, a sample from Well 02034 contained several organic compounds that were not detected in samples from the lakes. Downgradient of Ladora Lake, ground-water samples from Wells 02055 and 02056 are characterized as calcium carbonate. This chemistry differs from water samples from Ladora Lake, which are characterized as sodium carbonate.

Ground-water and surface-water interaction is indicated by water levels of Havana Pond, Upper Derby Lake, Lower Derby Lake, Ladora Lake, Lake Mary and proximal wells. Havana Pond appears to be recharging ground water to the north but due to the lack of monitoring wells the relationship in the other directions is unknown. In the Upper Derby Lake, Lower Derby Lake, Ladora Lake and Lake Mary areas, ground water appears to be discharging to the lakes from the east-southeast, and the lakes appear to be recharging the ground water toward the west-northwest. Near the east side of Ladora Lake, the water levels indicate that the upward direction of ground-water flow is from the Denver Formation (Well 02060) through the alluvium (Well 02059) to the lake.





EXPLANATION

Dissolved Concentration in Water

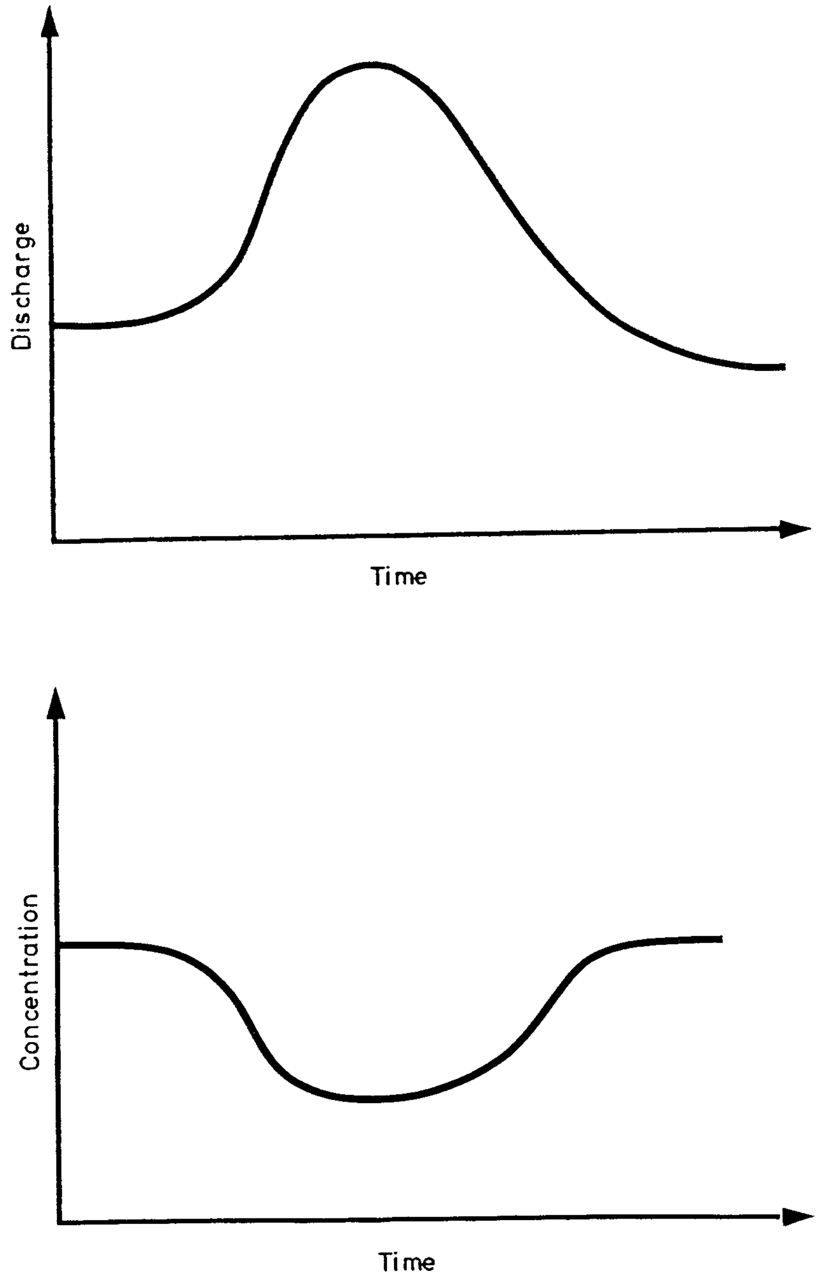
Prepared for :
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :
R.L. Stollar & Associates, Inc.
Harding Lawson Associates

Figure 5.2-1

Direct Relationship Between Discharge and Concentration

CMP SW FY89



EXPLANATION

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Figure 5.2-2

Inverse Relationship Between Discharge and Concentration

CMP SW FY89

6.0 CONCLUSION

6.1 Surface-Water Quantity Conclusions

Many of the surface-water flow-measurement problems of previous years were corrected before, or early in, the water year - resulting in an improved flow data set for the year. The addition of portable flumes to measure very low flows increased accuracy in the range from 0.03 cfs to 1.70 cfs. This flow data in turn was used to more accurately refine and define rating curves in this low flow range.

The major volume of surface-water inflow onto RMA occurs in the Irondale Gulch drainage basin with most of the flow being conveyed via the Havana Interceptor. These flows generally fluctuate more rapidly than First Creek inflow. This is primarily due to the higher extent of industrial and residential development immediately off-post from Irondale Gulch drainage basin than immediately off-post from First Creek. This of course will change with the construction of the new airport and associated development. During the past four years there has been a downward trend in flow measured at the Havana Interceptor monitoring station compared to precipitation measured at Stapleton Airport. Additional precipitation stations off-post and/or the addition of on-site RMA precipitation data obtained by CMP Air Element will aid in future trend analysis.

A large proportion of surface water flowing onto RMA is lost to deep seepage, evaporation and transpiration and does not appear as surface-water outflow. Most of the surface-water flowing onto RMA is stored in the South Plants Lakes and hence is allowed to infiltrate into the ground-water system and also allowed to evaporate. The ground-water and surface-water interaction data collected during Water Year 1989 showed that at various times of the year First Creek fluctuates between being a gaining and losing stream throughout RMA.

The addition of new controls on First Creek at South First Creek, North First Creek and First Creek Off-Post locations has stabilized the collection of discharge data at these locations. The previous controls had to be replaced due to stream modifications caused by on-post construction activities or control failure. The addition of new digital acquisition equipment (i.e., data loggers) has shown that accuracy of stage data has not been compromised as demonstrated in Section 4.1. This equipment has decreased data reduction turnaround time and increased the amount of stage data being accurately collected. Coupled with this new digital acquisition equipment and controls new nitrogen bubbler systems have been added at important surface-water locations on RMA. This bubbler system will allow for the collection of year-round stage data collection that includes collecting stage data during the freezing months of December through April. A preliminary assessment of this system indicates that this goal is being accomplished.

6.2 Surface-Water and Sediment Quality Conclusions

6.2.1 First Creek Drainage Basin

6.2.1.1 Organic Compounds in Surface Water. Four organic compounds that may be representative of surface water entering RMA were detected at upstream locations on First Creek: DBCP, dieldrin, endrin, and Vapona. With the exception of dieldrin, these chemicals were not detected in samples collected at locations along First Creek during FY88.

DBCP (a soil fumigant) was widely used at RMA, but no source areas are known to exist along First Creek. DBCP has been historically detected in samples from the entrance of First Creek onto RMA (SW08001), and the source of DBCP at this location is unknown.

Dieldrin and endrin are chlorinated insecticides that were manufactured at RMA. The low reported concentrations and sporadic detections suggest an inconsistent source of these chemicals at this location.

Vapona has not historically been included on target parameter lists; therefore, there are no historical sampling events to substantiate this detection. Vapona is an insecticide that was manufactured at RMA. Because the highest detection of Vapona was found near the South First Creek Boundary (SW08001), the existence of Vapona in the First Creek drainage basin is difficult to directly relate to runoff from potential on-post sources. The source of this chemical could be sediment material originating from either on-post or off-post source.

Two organic compounds were detected at the northern reach of First Creek. DMMP was detected in a sample from SW24001 (Sewage Treatment Plant), and DIMP was detected in a sample from SW24003 (North Bog). The occurrence of DMMP at SW24001 may relate to variations in the chemistry of the sewage discharge and/or the rate of discharge. DMMP was detected in a sample collected during a period of variable flow but was not detected in a sample collected during a period of constant flow. Although the water is sanitary sewer discharge, it is possible that organic chemicals have entered this system. Detections of DIMP at SW24003 have also occurred historically and may be related to the north boundary system.

Seven organic compounds were detected in a sample from First Creek Off-Post monitoring station (SW37001): atrazine, chlordane, DCPD, DIMP, dieldrin, endrin, and PPDDT. With the exception of DIMP, these compounds were not detected immediately upstream; therefore, the source does not appear to be upstream surface water. DCPD, DIMP, and dieldrin were detected in a sample from this location during FY88 but at lower concentrations, with the exception of dieldrin. A possible explanation is discussed below.

Six of the seven chemicals detected in the sample from SW37001 were also detected in a ground-water sample from nearby Monitoring Well 37343. With the exception of DCPD, the chemical concentrations were higher in the ground-water sample. The similarity in chemicals suggests that ground water is discharging in this area and subsequently mixing with surface water.

Although surface water was identified as a potential migration pathway for contaminants in the Eastern Study Area (Ebasco and others, 1989h), results from analysis of surface-water samples indicated that impacts to surface water derived from activities in the Eastern Study Area are minimal. According to the North-Central SAR (Ebasco and others, 1989f), surface-water samples collected from North Bog and First Creek (where it exits RMA) during the RI did not yield detections of potential contaminants. Based on the FY89 data, samples collected from North Bog and First Creek Off-Post did yield detections of potential contaminants.

6.2.1.2 Inorganic Constituents in Surface Water. Arsenic was the only trace inorganic constituent detected in samples collected along First Creek during FY89. SW08003 is a new sampling location established during FY89 because of the construction of a new monitoring/ gaging station. Arsenic was detected in samples collected from SW08001 and SW24001 during FY88 and from SW24001 during historical sampling events. The concentrations reported for these sampling events are comparable. The difference in arsenic concentrations between the upstream and downstream locations indicate unrelated sources. Additionally, because arsenic was detected in a sample from SW08001, the source may not be solely RMA.

In general, an inverse relationship (as idealized in Figure 5.2-2) between concentration and discharge was observed for the inorganic constituents detected in samples collected along the reach of First Creek. This inverse relationship occurred for both the trace constituents and major ions.

6.2.1.3 Organic Compounds in Stream-Bottom Sediments. Organophosphorus compounds were detected in six samples collected along First Creek. Atrazine was the compound detected most frequently in six of seven samples, including a sample from SW08001 (First Creek South Boundary). Although atrazine and other organophosphorus compounds were manufactured at

RMA, the occurrence of this compound in a sediment sample from SW08001 indicates the potential for a source other than RMA.

A comparison of organic compounds detected in stream-bottom sediments and surface-water samples from the same location indicates a difference in the compounds detected in each medium. The difference is most likely due to chemical properties, e.g., partitioning, associated with the chemicals.

6.2.1.4 Trace Metals in Stream-Bottom Sediments. Trace metals were commonly detected in stream-bottom sediment samples collected along First Creek. Trace metals were detected in five of seven samples. The concentrations were comparable, but the same suite of trace metals was not detected in each sample.

A comparison of trace metals detected in stream-bottom sediments and surface-water samples from the same location indicates a difference in the trace metals detected in each medium. The heavier trace metals (cadmium, chromium, and lead) were detected primarily in the stream-bottom sediment samples, and only arsenic was detected in surface-water samples.

6.2.1.5 Ground-Water/Surface-Water Interaction. The gain/loss data and chemical data collected and analyzed along First Creek indicate interaction between surface water and ground water. First Creek appears to be interacting with ground water at various points along First Creek and at various times of throughout the year.

The area near SW24002 is characterized as the transition between sodium carbonate and sodium sulfate surface water. Ground water from Well 24188, which is located immediately north of SW24002 and east of First Creek, is characterized by high concentrations of sodium and sulfate. Although different organic compounds were detected in surface-water and ground-water samples, the ion chemical data indicate that First Creek is gaining in this area as ground water discharges to surface water.

Similar organic chemical data for surface-water samples and ground-water samples near SW37001 indicate mixing. The major similarity is indicated in the organic data in that the same organic compounds were detected in samples from both waters. Concentrations in ground water were generally higher than in surface water, which indicates that ground water is discharging in this area and mixing with surface water.

Hydrographic data were not available to assess ground-water/surface-water interaction in the First Creek drainage basin. However, gain/loss data collected along the southern reach of First Creek on RMA show that First Creek is discharging to ground water.

6.2.2 Irondale Gulch Drainage Basin

6.2.2.1 Organic Compounds in Surface Water. Sixteen organic compounds that may be representative of surface water entering RMA were detected at sampling locations in the Irondale Gulch drainage basin. The compounds are aldrin, atrazine, chlordane, CL6CP, CMPSO, dieldrin, DIMP, DMMP, isodrin, parathion, PPDDE, PPDDT, Vapona, xylenes (o,p), 2,4,5-trichlorophenol, and 4-methylphenol.

Aldrin, dieldrin, CL6CP, and isodrin are associated with the manufacture of pesticides and are not necessarily exclusive to RMA activities. The source of these compounds at the southern boundary of RMA may be (1) runoff from on-post and/or off-post areas from RMA or (2) runoff from off-post areas to the south. These chemicals were also detected at sampling locations near South Plants.

Atrazine, parathion and Vapona are associated with the manufacture of insecticides and herbicides. These compounds were not historically included on target parameter lists for surface-water sample analyses; therefore, their historical distribution and occurrence are unknown. The detection of these compounds at the southern boundary of RMA could be related to sediments originating from off-post sources.

DIMP and DMMP are associated with the manufacture of GB (Sarin nerve gas). Their limited and sporadic detections at the southern boundary of RMA suggest an inconsistent source.

PPDDE and PPDDT are associated with the manufacture of pesticides. The detections of these compounds at the southern boundary of RMA could be related to sediments from on-post or off-post sources.

Chlordane is associated with the manufacture of insecticides. Although chlordane was detected at the southern boundary of RMA once during FY89, there have not been any historical detections. The detection at this location suggests an inconsistent source.

CPMSO was the chemical detected at the highest concentration at the southern boundary of RMA during FY89. Minimal historical detections of CPMSO suggest a limited source, possibly windblown material from RMA.

The phenols, 2,4,5-trichlorophenol and 4-methylphenol, were not historically included on target parameter lists for surface-water sample analyses; therefore, their historical distribution and occurrence are unknown.

Xylenes (o,p) are common industrial solvents. Their detection at the southern boundary of RMA is without historical precedent and may be related to the industrial area to the south.

The occurrence of many organic compounds along the southern boundary of RMA may or may not be related to RMA sources. Spurious and isolated detections indicate an inconsistent or nonpoint source. According to the Southern SAR (Ebasco and others, 1989b), surface water is a principal migration pathway for organochlorine pesticides in this study area. Organochlorine pesticides, volatile halogenated organics, and volatile aromatic organics were detected in samples of surface waters from ditches entering RMA from the Montbello industrial and residential area to the south. Samples collected from the southern boundary of RMA during FY89 also contained some of these organic compounds.

6.2.2.2 Inorganic Constituents in Surface Water. Water-quality baseline levels of trace metals in surface waters entering RMA from off-post sources at the southern boundary varied inconsistently as a function of discharge. The detections of trace metals during the FY89 sampling events were sporadic for samples from the same location and appeared to be unrelated to flow rate.

The trace metals detected in samples near the southern boundary of RMA were typical of runoff expected to originate from industrial areas. Although the suite of trace metals detected was similar to the trace metals detected in samples collected during FY88, the spatial distribution of the trace metals was different in FY89.

The detections of cyanide in two samples near the southern boundary of RMA (SW07001 and SW12001) were the only detections of cyanide reported for FY89. Cyanide has not been included on historical target parameter lists. Cyanide was not detected in any samples from the on-post area; therefore, the source of cyanide at the southern boundary appears to be unrelated to RMA activities.

In general, there was an inverse relationship (as idealized in Figure 5.2-2) between concentration and discharge for major ions detected in samples from the Irondale Gulch drainage basin. Data indicated both a direct and inverse relationship between concentration and discharge for trace metals detected in samples from the Irondale Gulch drainage basin.

6.2.2.3 Organic Compounds in Stream-Bottom Sediments. Organophosphorus compounds were detected in five samples collected along the southern boundary of RMA. Atrazine was the compound consistently detected in the five samples. The occurrence of these compounds at the southern boundary of RMA possibly indicates a source other than RMA.

A sample collected from one location (SW01002) that consistently contained organic compounds in surface water also contained organic compounds in the stream-bottom sediments. The presence of organic compounds in stream-bottom sediment and surface-water samples from the same location indicates the potential for interaction between the liquid and solid phases but does not necessarily indicate that an equilibrium condition exists.

6.2.2.4 Trace Metals in Stream-Bottom Sediments. Trace metals were commonly detected in stream-bottom sediment samples collected in the Irondale Gulch drainage basin. The concentrations and distribution of trace metals were not consistent among the sampling locations. The concentrations of trace metals in samples from the South Plants Lakes areas were generally higher compared to samples near the southern boundary of RMA. This difference in concentrations indicates that the presence of trace metals in the South Plants Lakes area could be related to RMA activities.

A comparison of trace metals detected in stream-bottom sediment and surface-water samples from the same location indicates a difference in the trace metals detected in each medium. The heavier trace metals (cadmium, chromium, copper, and lead) were detected primarily in the stream-bottom sediment samples, and only arsenic and zinc were generally detected in surface-water samples.

6.2.2.5 Ground-Water/Surface-Water Interactions. The ground water and surface water in the South Plants Lakes area are primarily characterized as either sodium carbonate or calcium carbonate. In many cases, the concentrations of calcium and sodium are close in magnitude. Although there appears to be similarities in the ionic data from ground-water and surface-water samples, the calculation of charge balances indicated two surface-water samples (SW01004 and SW01005) and six ground-water samples (01047, 01073, 02034, 02055, 02059 and 02060) with charge balance errors greater than five percent. The magnitude of this error therefore limits conclusions on the ground-water/ surface-water interactions in the South Plants Lakes area based on the ionic data.

Organic chemical data from surface-water and ground-water samples from the South Plants Lakes area do not indicate a definitive interaction between the two waters. Factors potentially limiting conclusions regarding interactions in this area include (1) significant dilution of any ground-water recharging the lakes or (2) the selection of wells for the comparison. The wells selected were the only wells sampled in the South Plants Lakes area in spring FY89 under the CMP ground-water element.

Although ion and organic chemical data are inconclusive, water-level data indicate interaction between the two waters in the South Plants Lakes area. Ground-water discharges to the lakes from the east-southeast and is recharged by the lakes to the north-northwest.

6.2.3 South Platte Drainage Basin

6.2.3.1 Organic Compounds in Surface Water. Basin A, the sampling location generally having the highest organic compound concentrations of the CMP surface-water sampling network, was sampled twice in FY89. The sample collected during the fall sampling event contained fewer compounds at lower concentrations than the sample collected during the spring sampling event, with a few exceptions. Flow was measurable during the fall sampling event (0.02 cfs), but the water was stagnant during the spring sampling event. The lower concentrations observed during the fall sampling event may be due to dilution with increased flow; this is indicative of an inverse relationship (as idealized in Figure 5.2-2) between concentrations and discharge. Additionally, the dilution would mask some compounds by decreasing their concentrations below the detection limit. A similar indirect relationship was observed in samples from this location in FY88. The sample collected during the FY88 fall sampling event contained more compounds at generally higher concentrations than the sample collected during the FY88 spring sampling event. Flow rates in FY88 fall (0.00002 cfs) were significantly lower than flow rates in FY88 spring (0.0003 cfs).

Four compounds detected at higher concentrations during the fall sampling event include aldrin, isodrin, PPDDT and Supona. The increases in concentrations varied by factors of two to four. Chemical transformation or biological degradation promoted by the stagnant conditions during the spring sampling event are two potential causes for this trend.

6.2.3.2 Inorganic Constituents in Surface Water. The trace metals detected in samples from Basin A were generally elevated in concentration compared to trace metals detected in samples near the southern boundary at RMA. In addition, arsenic was the only trace metal detected in samples collected during the spring and fall sampling events. The concentration of arsenic was lower in the sample collected during the fall sampling event compared to the sample collected during the spring sampling event. The presence of elevated concentrations of arsenic and mercury are most likely related to RMA activities.

In general, there was an inverse relationship (as idealized in Figure 5.2-2) between concentration and discharge for major ions detected in samples from the Basin A location. However, data indicated both a direct and inverse relationship between concentration and discharge for trace metals detected in samples from this location.

6.2.3.3 Organic Compounds in Stream-Bottom Sediments. The organic compounds detected in a stream-bottom sediment from Basin A were also detected in a surface-water sample from this location. The presence of the organic compounds is most likely related to RMA activities. In addition, the presence of organic compounds in samples from each medium indicates the potential for interaction between the liquid and solid phases but does not necessarily indicate that an equilibrium condition exists.

6.2.3.4 Trace Metals in Stream-Bottom Sediments. Trace metals were detected in stream-bottom sediment samples from the Basin A location but these detections were inconsistent between sampling events. The concentrations of trace metals in samples from the Basin A location were generally higher compared to samples near the southern boundary of RMA. This difference in concentrations indicates that the presence of trace metals at the Basin A location is most likely related to RMA activities.

A comparison of trace metals detected in stream-bottom sediments and surface-water samples indicates a difference in the trace metals detected in each medium. The heavier trace metals (cadmium, copper, mercury, and lead) were detected primarily in the stream-bottom sediment samples, and generally only arsenic and zinc were detected in surface-water samples.

6.2.4 Sand Creek Drainage Basin

6.2.4.1 Organic Compounds in Surface Water. The one detection of dieldrin during a storm event and no historical detections of organic compounds from the Motor Pool (SW04011) suggest an inconsistent source that may or may not be related to RMA activities.

6.2.4.2 Inorganic Constituents in Surface Water. Zinc was the only trace metal detected in a sample from the Motor Pool (SW04001). The concentration of zinc was not elevated with respect to water-quality baseline levels established at the southern boundary of RMA and therefore, may be reflective of natural background concentrations.

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